भारत दूरसंचार
INDIA TELECOM

Coalition for Disaster Resilient Infrastructure

National and Sub-national Disaster Risk and Resilience Assessment and Roadmap for India's Telecommunications Sector

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Abbreviation

A	
APDCL	Assam Power Distribution Company Limited
ARPU	Average Revenue Per Unit
ASDMA	Assam Disaster Management Authority
B	
BA	Business Analytics
BBNL	Bharat Broadband Network Limited
BDOs	Block Development Officers
BMTPC	Building Materials and Technology Promotion Council
Bn	Billion
BSC	Base Station Controller
BSNL	Bharat Sanchar Nigam Limited
BSS	Broadcasting Satellite Service
BTS	Base Transceiver Station
BWA	Broadband Wireless Access
C	
CAGR	Compound Annual Growth Rate
CAP	Common Alerting Protocol
CAPA	Corrective And Preventive Actions
CB	Cell Broadcast
CBA	Cost Benefit Analysis
CBuD	Call Before you Dig
CCA	Controller of Communication Accounts
CDMA	Code-Division Multiple Access
C-DOT	Centre for Development of Telematics
CGCA	Controller General of Communication Accounts
CI	Critical Infrastructure
CIRI	Critical Infrastructure Resilience Index
CLS	Cable Landing Station
COAI	Cellular Operators Association of India
CoWs	Cell on Wheels
CROPC	Climate Resilient Observing Systems Promotion Council
CRS	Carrier Routing System
CUG	Closed User Groups
D	
DAMPS	Disaster Assistance Monitoring Payment System
DBN	Digital Bharat Nidhi
DC	Data Centres

Abbreviation

DDMA	District Disaster Management Authority
DEOCs	District Emergency Operating Centres
DFID	Department for International Development
DG	Diesel Generator
DGT	Director General Telecom
DHS	Department of Homeland Security
DIPA	Digital Infrastructure Providers Associations
DM	District Magistrate
DMR	Digital Mobile Radio
DoT	Department of Telecommunications
DPL	Dealer Possession License
DRI	Disaster Risk Index
DRIMS	Disaster Reporting and Information Management System
DRRAF	Disaster Risk and Resilience Assessment Framework
DSL	Digital Subscriber Line
DTH	Direct To Home
DRTF	Disaster Response Task Force
DWDM	Dense Wavelength Division Multiplexing
E	
EMF	Electromagnetic Force
EOC	Emergency Operating Centre
ERNET	Education and Research Network of India
ETSI	European Telecommunications Standards Institute
EU-Circle	European Union-Circle
EWDS	Early Warning Dissemination System
F	
FDD	Frequency-Division Duplexing
FGD	Focus Group Discussions
FSS	Fixed-Satellite Service
FTTH	Fibre to the Home
FTTx	Fibre to the x
G	
GDP	Gross Domestic Product
GEO	Geostationary Earth Orbit
GHz	Gigahertz
GIS	Geographic Information System
GMDSS	Global Maritime Distress and Safety System
GoI	Government of India

Abbreviation

Govt.	Government
GPs	Gram Panchayat
GSI	Geological Survey of India
GSM	Global System for Mobile Communications
GSMA	Global System for Mobile Communications Association
GSO	Geostationary Orbit Satellite
H	
HAPS	High-Altitude Platform Station
HTSs	High-Throughput Satellites
I	
IA	Internal Audit
ICR	Intra Circle Roaming
ICT	Information and Communications Technology
ILD	International Long distance
IMD	Indian Meteorological Department
INMARSAT	International Maritime Satellite Organization
INSAT	Indian National Satellite System
IoT	Internet of Things
IP	Internet Protocol
IPLC	International Private Leased Circuit
IPTV	Internet Protocol Television
IRPF	Infrastructure Resilience Planning Framework
IRTs	Indian Railway Traffic Service
IS	Indian Standards
ISP	Internet Service Provider
ISpA	Indian Space Association
ISPAI	Internet Service Providers Association of India
ISPs	Internet service providers
ISRO	Indian Space Research Organisation
IT	Information Technology
ITIL	Indian Telephone Industries Limited
ITU	International Telecommunication Union
IXP	Internet Exchange Points
K	
KII	Key Informant Interviews
Km	Kilometre
KPIs	Key Performance Indicators
KUSUM	Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan

Abbreviation

L	
LEO	Low Earth Orbit
LR	Licensing and Regulation
LSA	Licensed Service Area
LTC	Leave Travel Concession
LTE	Long-Term Evolution
LWE	Left Wing Extremism
M	
M2M	Machine to Machine
MEC	Multi-access Edge Computing
MEO	Medium Earth Orbit
MEOW	Mobile Exchange on Wheels
Mhz	Megahertz
MoUs	Memorandum of Understanding
MPLS	Multiprotocol Label Switching
MPVT	Mandatory Performance Verification Testing
MSC	Mobile Switching Centre
MSS-R	Mobile Satellite System-Reporting Service
MTNL	Mahanagar Telephone Nigam Limited
MW	Megawatt
N	
NBC	National Building Code
NCCS	National Centre for Communications Security
NCR	National Capital Region
NDCP	National Digital Communications Policy
NER	North Eastern Region
NGO	Non-Government Organization
NICF	National Institute of Communication Finance
NLD	National Long Distance
NOCC	Network Operation and Control Section
NPV	Net Present Value
NTG	New Technology Group
NTIPRIT	National Telecommunications Institute for Policy Research, Innovation and Training (now known as National Communications Academy)
O	
OFC	Optical Fibre Cable
OLT	Optical Line Terminal
ONT	Optical Network Terminal

Abbreviation

P	
PBG	Performance Bank Guarantee
PCO	Public Call Office
PIP	Policy Institutions & Processes
PLCC	Power Line Carrier Communication
PMRTS	Public Mobile Radio Trunking Services
PM-WANI	Prime Minister Wi-Fi Access Network Interface
POIs	Points of Interconnection
PoP	Point-of-Presence
PPDR	Public Protection and Disaster Relief
R	
RDAT	Rapid Damage Assessment Team
RDSS	Revamped Distribution Sector Scheme
RE	Renewable Energy
RI	Resilience Index
RNC	Radio Network Controller
RoW	Right of Way
RS	Resilience KPI Score
RTR	Radio Telephony Restricted
RTT	Roof Top Tower
RTTs	Radio Transmission Towers
S	
SACFA	Standing Advisory Committee for Frequency Allocation (India)
SAMPANN	System for Accounting and Management of Pension
SAS	Security Assurance Standards
SatCOLT	Satellite Cell on Light Truck
SATCOM	Satellite Communication
SBMDV	Satellite-Based Mobile Data Voice Terminal
SC	Security Certification
SCADA	Supervisory Control and Data Acquisition
SDH	Synchronous Digital Hierarchy
SDMA	State Disaster Management Authority
SEOC	State Emergency Operating Centre
SESG	Satellite Earth Station Gateway
SLR	Security Lab Recognition
SMC	Submarine Cable
SMS	Short Message Service
SoI	Survey of India
SOP	Standard Operating Procedure
SPV	Special Purpose Vehicle
SSA	Secondary Switching Area
SUC	Spectrum Usage Charges

Abbreviation

T	
TAFS	Telecommunication Accounts and Finance Service
TAIPA	Tower and Infrastructure Providers Association
TCIL	Telecommunications Consultants India Limited
TDD	Time-Division Duplexing
TDSAT	Telecom Dispute Settlement and Appellate Tribunal
TEC	Telecommunications Engineering Centre
TIA	Telecommunications Industry Association
TRAI	Telecom Regulatory Authority of India
TSDSI	Telecommunications Standards Development Society, India
TSPs	Telecom Service Providers
U	
UAE	United Arab Emirates
UL	Unified License
UNDRR	United Nations Office for Disaster Risk Reduction
US	United States
USAID	United States Agency for International Development
USD	United States Dollar
USOF	Universal Service Obligation Fund
UT	Union Territory
V	
V2R	Vulnerability to Resilience
VHF	Very High Frequency
VPNs	Virtual Private Networks
VSAT	Very Small Aperture Terminal
VSNL	Videsh Sanchar Nigam Limited
W	
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WMO	Wireless Monitoring Organisation
WPC	Wireless Planning and Coordination

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State

State Disaster Management Authority (SDMA): Assam, Odisha, Tamil Nadu, Gujarat, Uttarakhand

Local Service Area (LSA) Office: Assam, Tamil Nadu, Gujarat, Uttar Pradesh (West)

Line Departments:

Odisha: Electronics and Information Technology, Industries, Odisha Computer Application Centre, Odisha Space Applications Centre, Odisha Power Transmission Corporation Limited

Assam: Public Works Department- Building, Power, Agriculture, Industries, Commerce and PE, Public Works Department - Road, Assam Electronics Development Corporation Limited (AMTRON), Panchayat & Rural Development, Fire & Emergency Services, Assam Energy Development Agency, Housing & Urban Affairs, Guwahati Metropolitan Development Authority, Assam Electricity Grid Corporation Limited, Assam Power Distribution Company Limited, Water Resource Department, Health & Family Welfare, Assam Power Generation Corporation Limited

Tamil Nadu: Forest Department, Department of Environment and Climate Change, Tamil Nadu Generation and Distribution Corporation Ltd., Highways and Minor Port, Fire and Rescue Services

Gujarat: State Emergency Operations Centre, Climate Change Department, Ports and Transport Department, Gujarat State Road Transport Corporation, Roads and Buildings Department, Panchayat and Rural Housing Department, Tourism Department, Department of Science and Technology, Institute of Seismological Research, Information Department, Energy and Petro-Chemicals Department, Gujarat Urja Vikas Nigam Limited, ICT and e-Governance Department, TSTCL-TIL, BISAG-N

Uttarakhand: Information Technology Development Agency, Uttarakhand Disaster Recovery Project, Public Works Department, Uttarakhand Forest Department, Uttarakhand State Council for Science And Technology, Uttarakhand Power Corporation Limited, Uttarakhand Power Corporation Limited, Indian Institute of Remote Sensing (IIRS), Fire and Emergency Services Department, Drone Application and Research Centre.

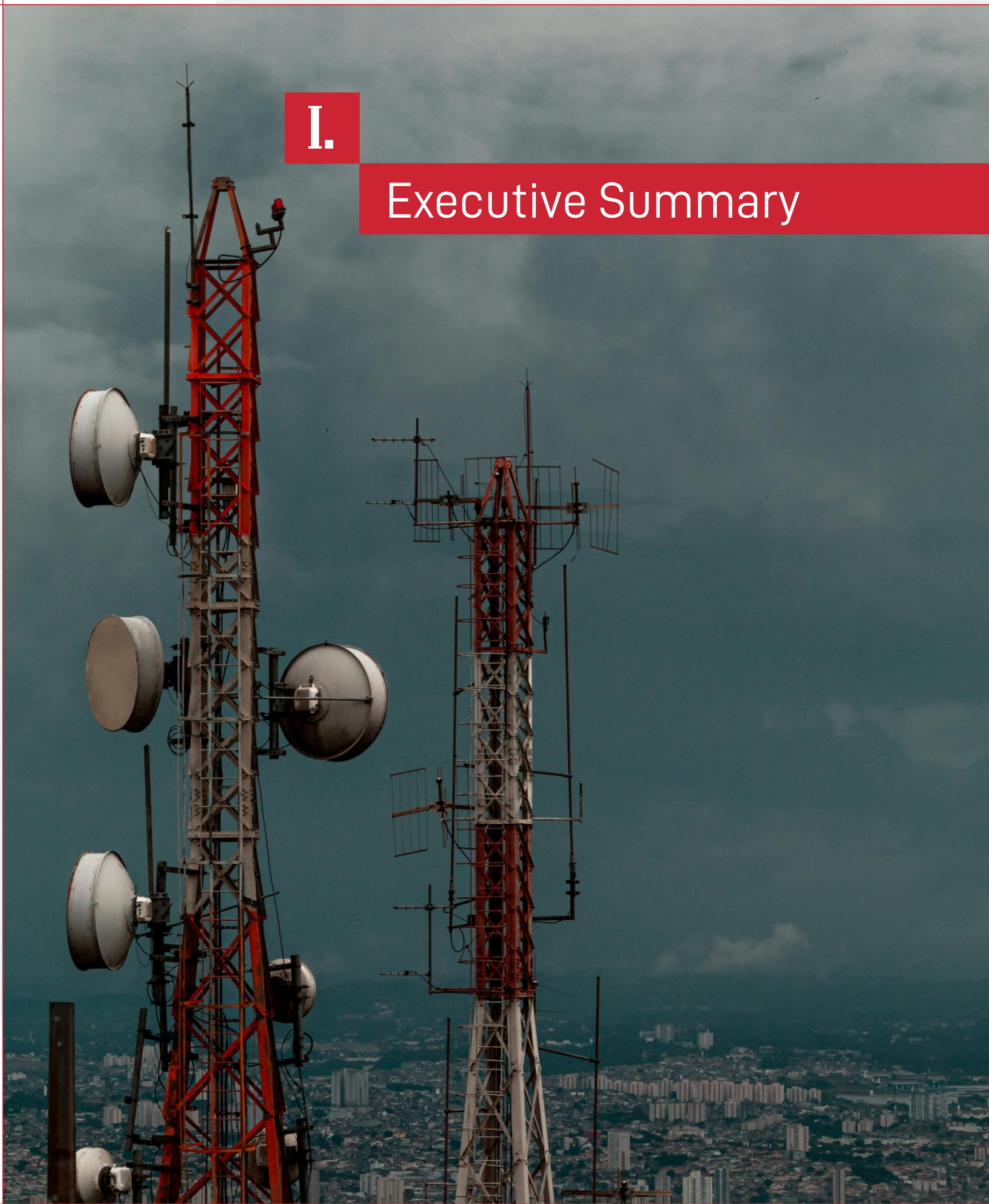
Districts and Blocks

District Disaster Management Authority (DDMA): Odisha: Ganjam, Puri, Jagatsinghpur; Assam: Dibrugarh, Cachar, Dima Hasao; Tamil Nadu: Tiruvallur, Nilgiris, Cuddalore; Gujarat: Gir-Somnath, Surat, Jamnagar; Uttarakhand: Dehradun, Rudraprayag, Pithoragarh

Block and Communities: Ganjam (Chattrapur, Ganjam Rangeilunda), Puri (Krushnaprasad, Gop, Puri), Jagatsinghpur (Kujanga, Tirtol, Erasama); Dibrugarh (Panitota, Barbaruah, Lahowal), Cachar (Borkhola, Kalain, Katigorah), Dima Hasao (Haralgajao, Mahur) Gir-Somnath (Veraval, Sutra-Pada, Una), Surat (Surat Urban Block), Jamnagar (Lalpur and Jamnagar Rural Block); Dehradun (Chakrata and Kalsi), Rudraprayag (Agastyamuni), Pithoragarh (Munsiyari, Dharchula)

Telecommunication Operators: Reliance Jio Infocom., Vodafone Idea Limited, Bharti Airtel Limited, Indus Towers, Tower Vision India & Ascend Telecom, BSNL, Summit DigiTel, American Tower Corporation (ATC), BSNL (Landing Station), TATA Communication Limited, Countrylink Communication Private Limited, HCPL Unlimited Internet Services.

I. Executive Summary



Executive Summary

Disaster impacts the infrastructure systems across the globe. Telecommunication, one of the critical infrastructure systems, plays a crucial role in contributing to the country's economic growth and connecting the last mile. Over the past decade, the telecommunications sector has contributed approximately 15 percent to global GDP and by 2030, the sector is projected to reach US$2.8 trillion, with a Compound Annual Growth Rate (CAGR) of about 6.2 percent between 2024-30. As the digital economy expands, it becomes essential to protect this infrastructure system from the increasing impact of natural hazards. According to the United Nations INFORM risk index, India is ranked 35th out of 191 countries in 2024-25[1]. In India, over 58 percent of the land is vulnerable to earthquakes, 12 percent to floods, 15 percent to landslides, and more than 10 percent to forest fires. Post-COVID-19 outbreak and the UN's 2027 target of disseminating warnings to the last mile further emphasize the need to build a robust and resilient telecommunication infrastructure nationwide.

To address the disaster risk challenges arising across the telecommunication infrastructure system, Coalition for Disaster Resilient Infrastructure (CDRI) conducted a national and sub-national scale study for disaster risk and resilience assessment of the telecommunications sector in India. The study adopts a multi-hazard assessment approach for telecommunications and its interconnected infrastructure system across various geographies vis-a-vis mountains, plains, and coasts. It considers different technological options: terrestrial, underground, and space, across three miles of telecommunications network. The study also deep dives into the upstream and downstream impacts on the interdependent infrastructure systems for all phases of disaster (pre, during, and post).

The study carried out an in-depth analysis of the telecommunications infrastructure's current state, using a unified approach (secondary research and field consultation) to evaluate the underlying disaster risk of the sector considering a comprehensive assessment of institutional setup, operation and maintenance practices, infrastructure standards, disaster management aspects in telecommunications policies, licensing and spectrum arrangement, existing capacity gaps and required financial arrangements for different phases of disaster. More than 100 stakeholder groups (including communities)

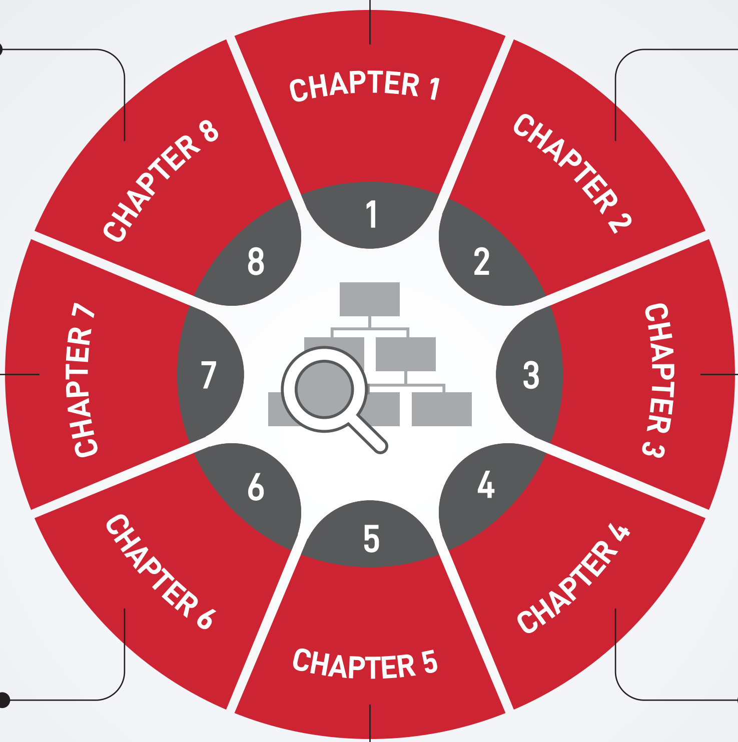
were consulted from national to block level to understand the on-ground challenges and needs at different levels. Further, a GIS-based multi-hazard risk mapping of telecommunications assets at the last mile identifies the assets' vulnerability at local, regional and national scales. This information helps stakeholders plan resilience interventions required for different geographies, adapting from global to local good practices.

A Disaster Risk and Resilience Assessment Framework (DRRAF) specifically tailored to the needs of the telecommunications sector, has been conceptualized by adapting key elements from various global infrastructure resilience frameworks. The framework includes two integrated layers: risk and resilience layers. These layers act as a feedback loop for each other to inform and continuously understand the risk required for resilience building. They also include an integrated monitoring and evaluation mechanism that guides stakeholders to learn, take corrective actions and adapt rapidly to emerging and extreme disaster risks.

The report highlights numerous action points for national and sub-national stakeholders across five domains of Policy, Planning and Institutions, Technical Planning and Design, Operation and Maintenance, Financial Arrangements and Incentives, and Expertise. A short- to medium-term roadmap is proposed to update disaster damage & loss data format, mainstream disaster risk modelling into telecommunications infrastructure planning across all miles, strengthen telecommunications asset design based on local and regional hazard vulnerability profiles, map the optical fibre network on GIS platform, community awareness programme for Intra-Circle Roaming (ICR) activation, install telecommunications tower in disaster shelter premises through a cost-sharing model, comprehensive assessment for pre-positioning of temporary telecommunications network and broader adoption of High Altitude Platform System (HAPS) to establish emergency connectivity. An additional long-term roadmap proposes developing a single window permission system, adding redundancy to the existing network, increasing latency for better interoperability with SATCOM technologies, provision for annual budget allocation to strengthen disaster resilience of infrastructure systems, parametric insurance products to extend disaster risk financing support, provision of specialized Indian shipping vessels for faster restoration of submarine cables and developing a countrywide network resilience index.

The roadmap will help achieve key outcomes such as reduced physical damage and financial losses, rapid service restoration, robust disaster response, improved emergency connectivity, peer-to-peer knowledge exchange, and sectoral capacity building. The study offers a pathway to bolster the disaster resilience of the telecommunications sector to withstand and recover from natural hazards, ensuring seamless connectivity and service delivery even under extreme conditions.

Structure of the report



Background

Emphasizes the need to enhance disaster resilience of telecommunication infrastructure

Study design

The approach and methodology used to develop the Disaster Risk and Resilience Assessment Framework (DRRAF) and an actionable

The state of telecommunications sector, India

The telecommunication infrastructure landscape, policies, and standards in the country

Global insights and India's initiatives towards disaster resilient telecommunications

Reviews global best practices and India's strategies for building disaster-resilient telecommunication infrastructure

Multi-hazard risk mapping of telecommunication assets

The multi-hazard risk assessment of the telecommunications assets across national and sub-national scale

Transforming catastrophe into continuity: A disaster resilience framework

Introduction of the Disaster Risk and Resilience Assessment Framework (DRRAF) for India's telecommunications sector, detailing its components, KPIs and layered structure, along with the risk and resilience index

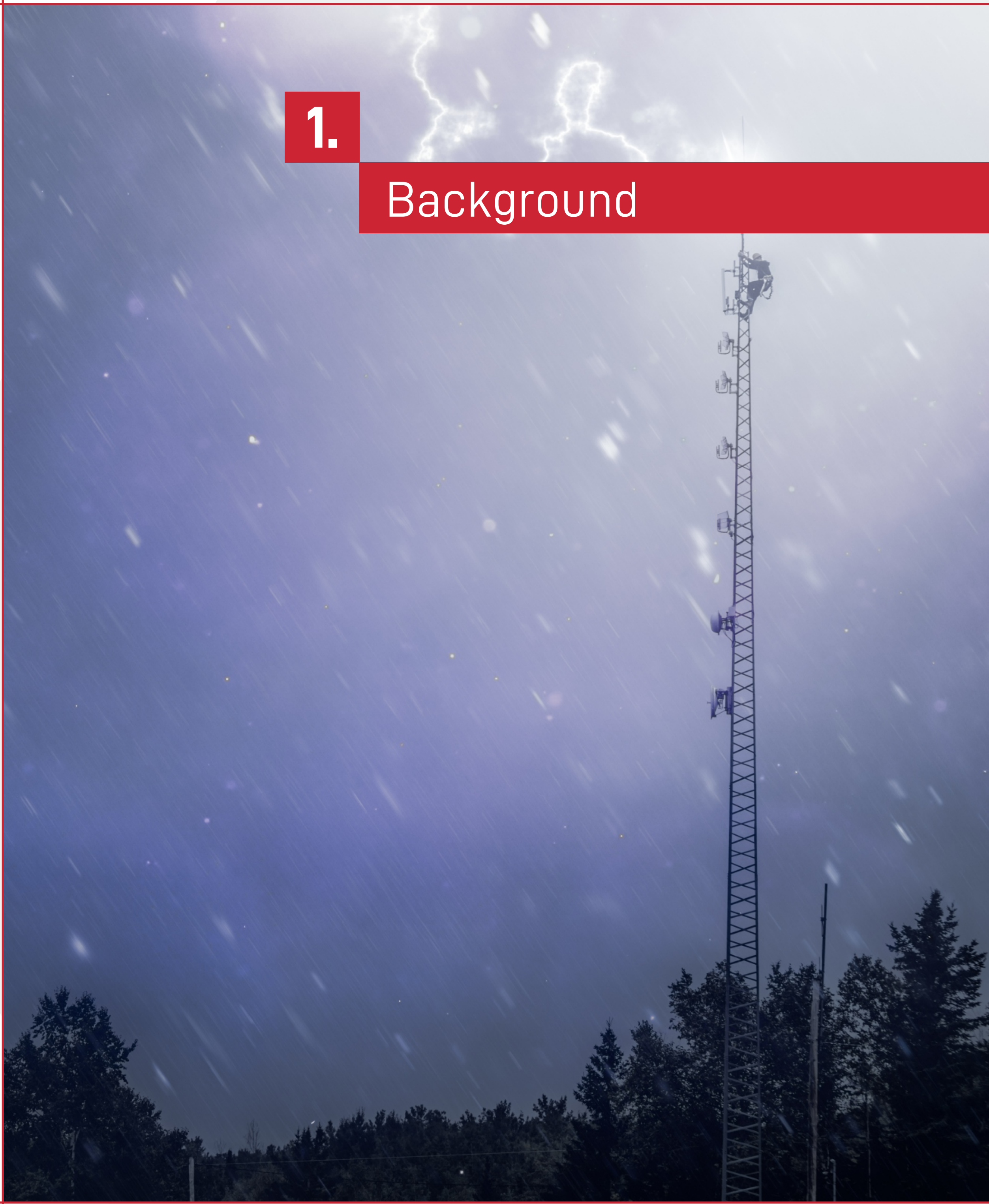
Key recommendations

Recommendations to strengthen the telecommunications sector resilience

Actionable roadmap

A roadmap and strategies to enhance disaster resilience in India and selected five states' telecommunication sector

1. Background



1.1. Telecommunications infrastructure system: Linking the globe

The telecommunications sector is pivotal in driving the global economy, fostering social development and enhancing connectivity. Over the past decade, it has contributed nearly 15 percent to the world's gross domestic product (GDP). According to Grand View Research, the telecommunications market is projected to reach US$ 2.8 trillion by 2030, with a compound annual growth rate (CAGR) of approximately 6.2 percent from 2024 to 2030.[1] This growth is fuelled by factors such as the deployment of 5G technology, the rise of Internet of Things (IoT), increased mobile penetration and broadband expansion. Approximately 68 percent of the world's population or 5.5 billion people are online.[2] Figure 1.1 provides a snapshot of global penetration rates for various information and communications technology (ICT) indicators.

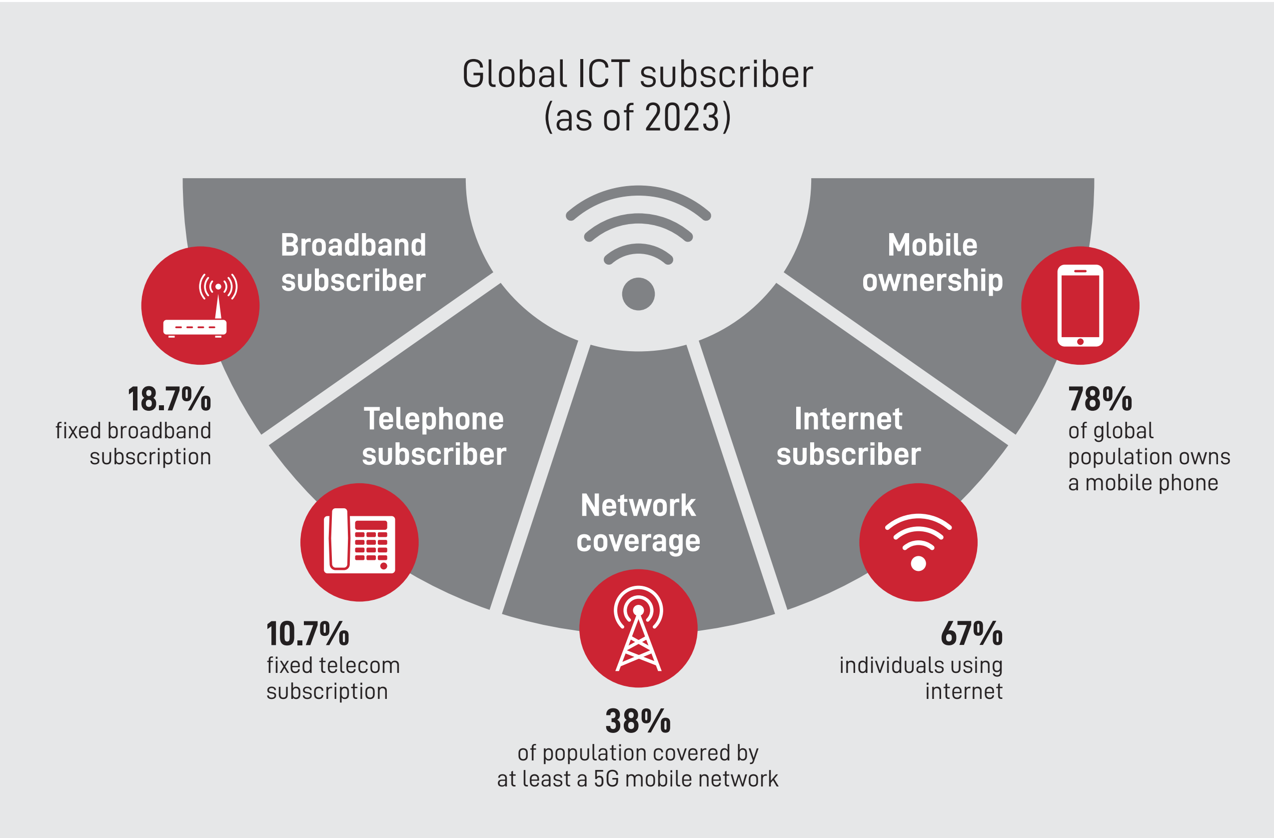


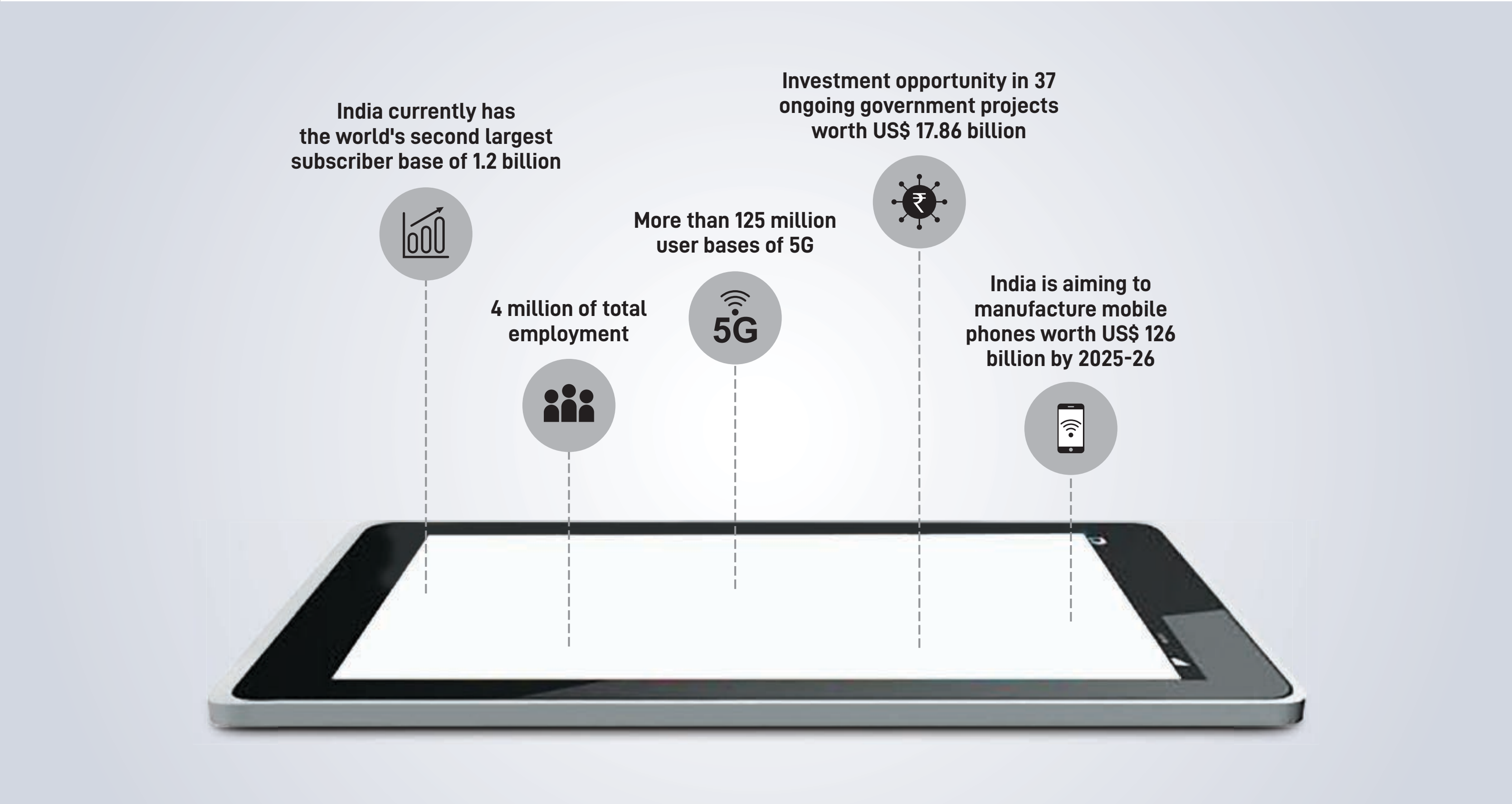
Figure 1.1 : Global ICT subscribers (as of 2023)
Source: ITU

As of July 2024, the Indian telecommunications market is the world's second largest, boasting a subscriber base of 1.2 billion (wireless + wireline subscribers). As per the Global System for Mobile communications Association (GSMA), India is projected to become the second-largest smartphone[3] market in the world by 2025, with around 1 billion installed devices. By then, the country is expected to have 920 million unique mobile subscribers, including 88 million 5G connections. Additionally, data usage is anticipated to increase further.[4] In the 2023 Network Readiness Index, India ranks 60 and holds the third position in 'Annual investment in telecommunication services' and 'Domestic market size'.[5] The market size is estimated to reach US$ 76.16 billion by 2029, growing at a 9.40 percent CAGR.[6] As the second-largest market globally with the third-highest internet users worldwide,[7] the Indian telecom sector holds immense potential for driving a US$1 trillion digital economy and a US$ 5 trillion Indian economy by 2025.[8] According to GSMA, 5G technology alone is expected to contribute US$ 450 billion to the Indian economy between 2023 and 2040.[9]

From 2014 to 2022, the Indian telecommunication sector saw remarkable growth, with a 25 percent increase in telephone connections, a 232 percent rise in internet connections, and a staggering 1238 percent surge in broadband connections.[10] Currently, India boasts a tele-density of approximately 85 percent, positioning the telecommunication system as a critical utility infrastructure for last-mile connectivity and downstream service delivery in both urban and rural areas. The Indian telecommunications sector offers diverse technological platforms, from 2G to 5G, ensuring comprehensive first-mile, middle-mile, and last-mile connectivity.

The telecommunications industry in India is experiencing significant expansion, driven by the increasing adoption of end-user applications and the growth of markets such as IoT, cloud computing, data centres and 5G technology. The liberation of markets and reformist telecom policies of the Government of India have played a crucial role in this rapid growth, complemented by strong consumer demand. The government has facilitated easy market access to telecommunications equipment and established a fair and proactive regulatory framework, ensuring that telecommunications services are available to consumers at affordable prices. As demand for telecommunications services continues to rise, the industry is poised to grow further in the coming decade.

Facts about Indian telecom sector



Indian telecommunications sector landscape

Figure 1.2 shows the current landscape of the Indian telecommunications sector. Detailed individual indicators have been discussed in the subsequent chapters of this document.[11]

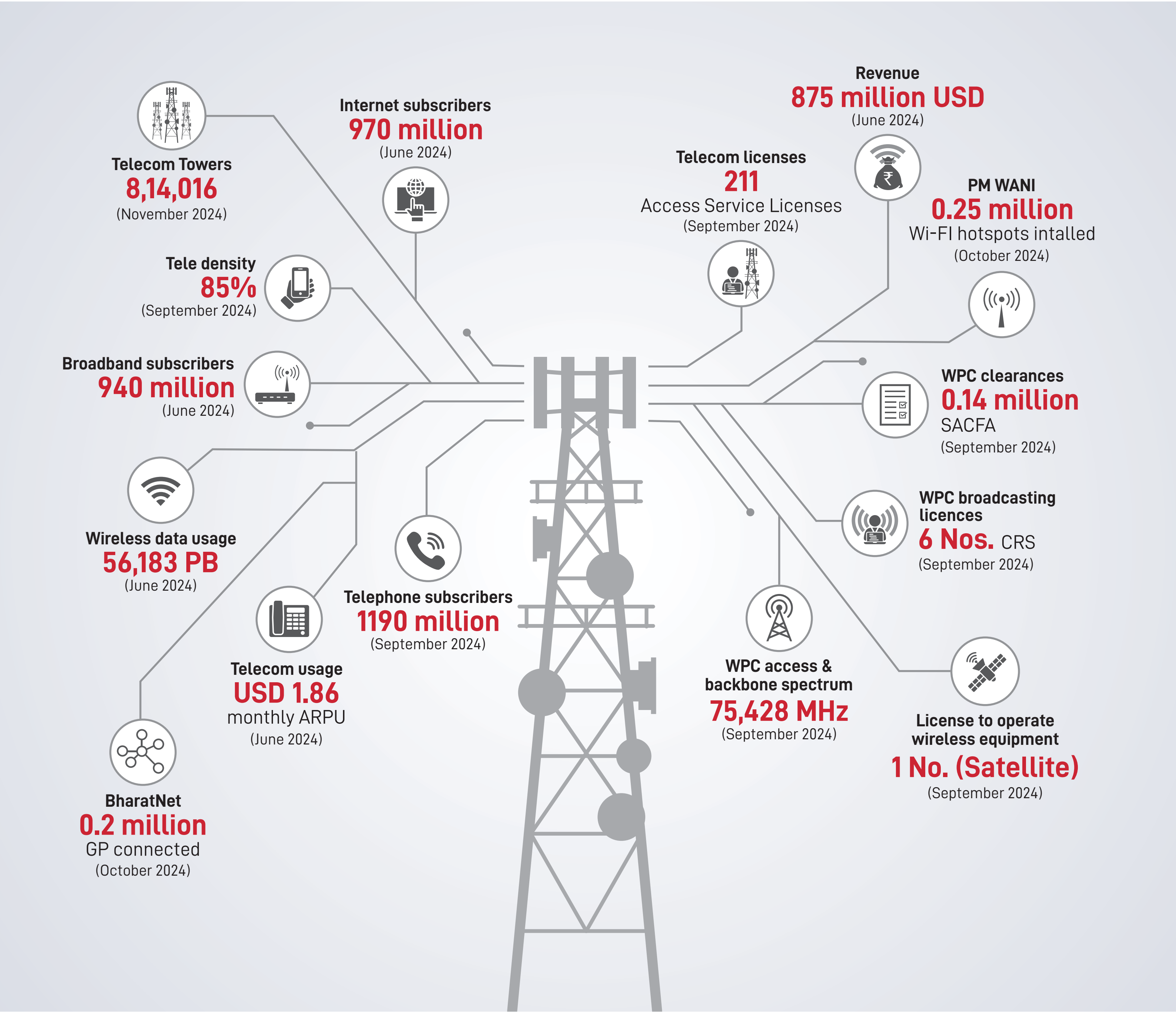


Figure 1.2 : Current landscape of the Indian telecommunications sector
Source: DoT Dashboard

1.2. Impact of disasters on telecommunications infrastructure systems

Disaster risk for infrastructure systems refers to the likelihood of damage and financial losses resulting from disaster over a specific period. Natural hazards significantly impact infrastructure systems, causing extensive damage and losses throughout their value chain.[12] These effects extend beyond the infrastructure sector, leading to compounding economic losses. Since the 1960s, the frequency of natural hazards has increased tenfold,[13] with the financial impact surging from US$ 50 billion per year in the 1980s to US$ 200 billion per year in the last decade. These impacts are expected to intensify, with limited predictability of their magnitude, affecting everything from infrastructure to service delivery. Natural hazards like earthquakes, hurricanes and floods can damage telecommunications infrastructure, such as cell towers, fibre-optic cables and data centres. This damage leads to service outages and increased repair and reconstruction costs. Additionally, network operations face challenges such as restricted site access, overloaded networks and potential data loss,[14] which disrupt service provision and reduce service quality.[15] These cascading risks highlight the urgent need for robust disaster preparedness and mitigation strategies across the telecommunications ecosystem.[16]

Telecommunications systems are particularly vulnerable to natural hazards due to various degrees of exposure of their asset elements, such as cell towers, antennas, cables, auxiliary power systems, switching stations, etc. Each of these elements faces unique risks during disasters, resulting in varying scale of disruptions to telecommunication system. Disasters often result in the power failure, asset inundation, antenna misalignment, damage to cell towers and cables, etc. Moreover, the interconnected and vast network systems, restrict quick access of the sites and speedy resolution during disaster. Poor awareness of Intra Circle Roaming (ICR) service activation across the community, increased network congestion and, limited availability of fuel and alternate telecommunication technologies at the site of disasters further aggravates the disruption of services.

The infrastructure and its impact on the climatic event at the asset level, network level and system-wise level are shown in Figures 1.3 and 1.4.

USA hurricane Katrina, 2005

3 million subscriber lines, **1,000** mobile towers, 38 '911' emergency call centres, and about **100** broadcast stations were impacted

Japan earthquake, 2011

29,000 mobile base stations were shut down

The Netherlands flood, 2021

Approximately **7,000** households were affected by disruption of telecommunications services

Tonga volcanic eruption, 2022

872 km / 541.8 miles of undersea fibre optic cable got impacted

Taiwan earthquake, 2024

200 base stations got impacted

Hawaii wildfire, 2023

14,466 subscribers were impacted

Figure 1.3 : Impact of disaster events on telecommunications infrastructure system: Global

Cyclone Fani, Odisha, 2019

6,058 BTS, **450 km (279.6 miles) optical fibre** were impacted

Cyclone Biparjoy, Gujarat, 2023

2,152 BTS were impacted due to power outages

Assam flood, 2024

646 out of 60,948 BTS were non-operational

Chennai flood, 2015

US$ **36.14 million** (₹ 300 crores) financial loss to telecommunications operators

Sikkim flood, 2023

166 BTS were impacted

Bhuj earthquake, 2001

The **telecom building** in Bhuj collapsed

Figure 1.4 : Impact of disaster events on telecommunications infrastructure system: India

1.3. Ensuring service continuity through disaster resilience at the system scale

Disaster resilience refers to the ability of a system exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.[17]

Today's communication system consists of many interconnected and interdependent nodes. Any risk affecting these nodes can trigger both cascading and compounding effects throughout the network. The failure, whether partial or complete, of a single component can significantly impact interconnected and interdependent systems, leading to what is known as 'systemic risk'. This concept has garnered considerable attention from decision-makers and the scientific community at both global and national levels, emphasizing the urgent need for resilience strategies at the system level.

The communication sector not only provides a technological foundation for communications but also plays a pivotal role during and after a disaster by ensuring timely flow of critical information. Hence, enhancing disaster resilience of the sector is crucial. The disaster impact data from two countries India and Japan both highly prone to earthquakes and cyclones, clearly highlights the need for strengthening disaster resilience of the telecommunications sector. Refer to Figure 1.5.

Systemic Risk

It is a combination of both tangible (equipment, people, property, financial resources) and intangible (processes, policies, information dissemination structure, relationships, values) risks.

- Mitra & Shaw (2023)

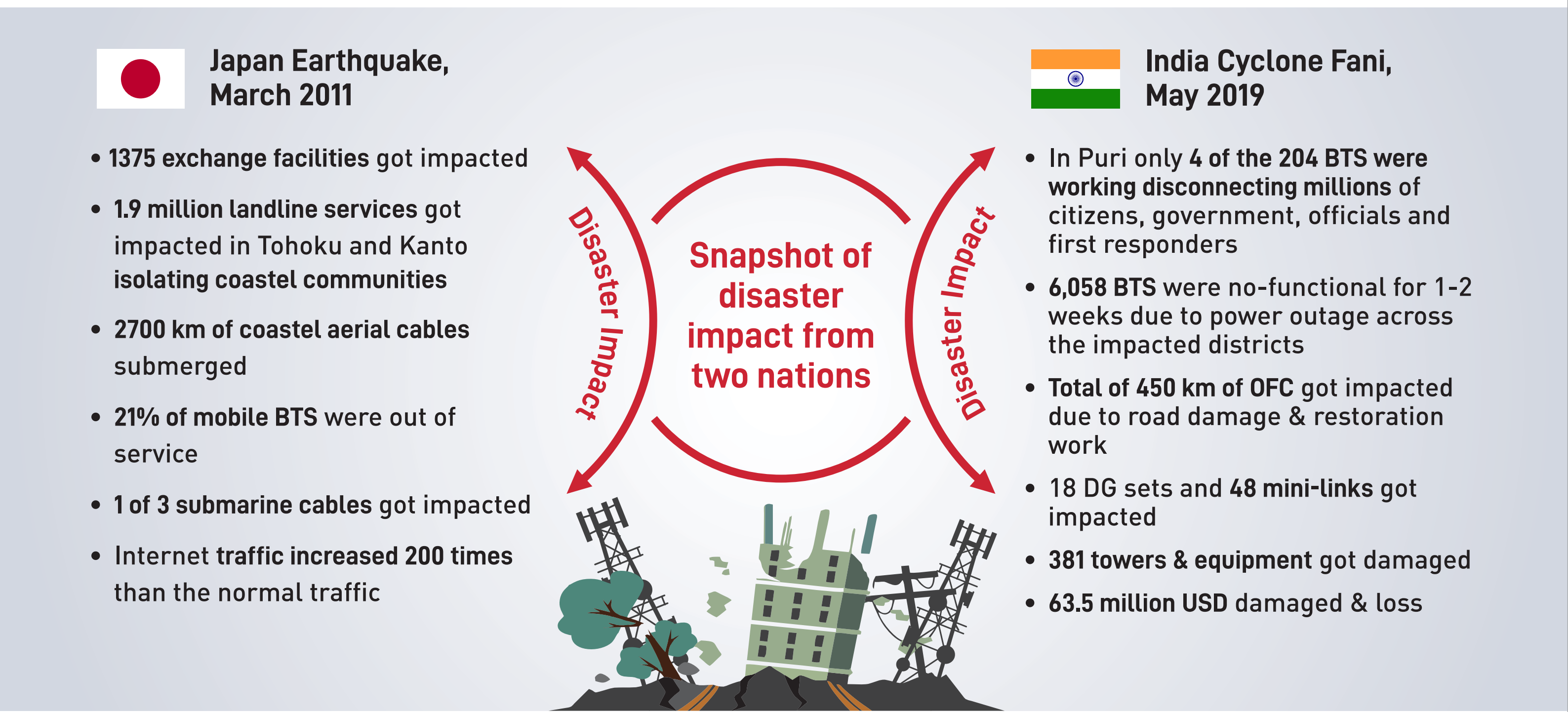


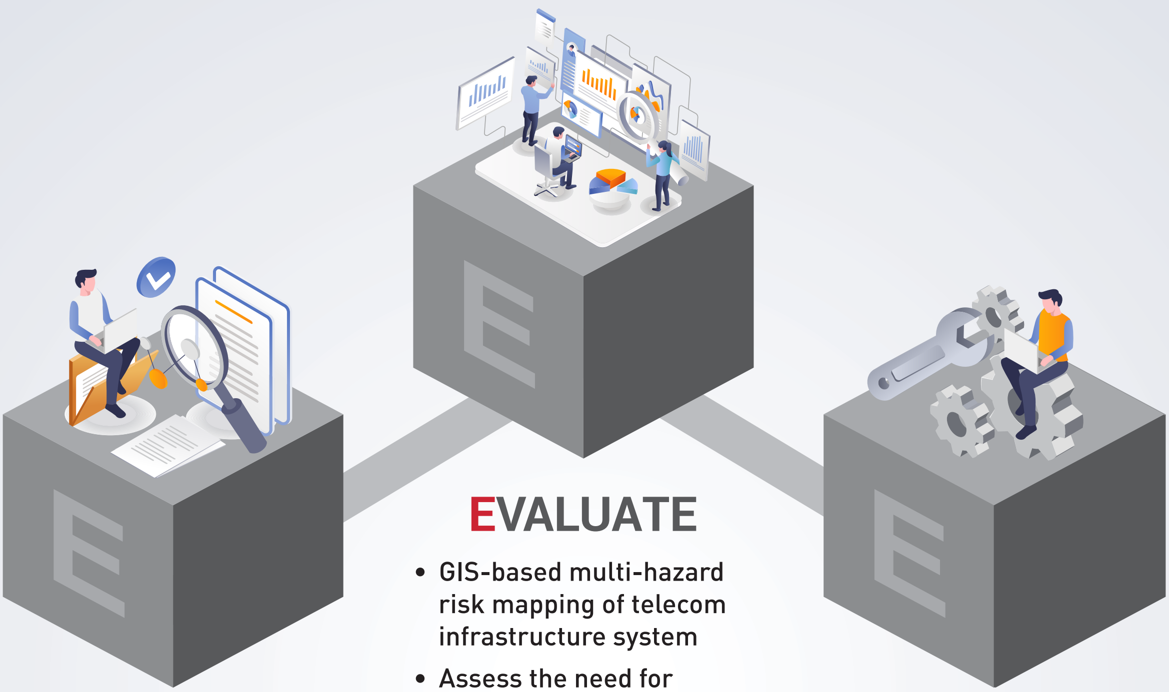
Figure 1.5: Snapshot of disaster impact from India & Japan

Enhancing the resilience of telecommunications on a systemic scale offers two key benefits. First, it increases the robustness of telecommunications assets at all operational levels. Second, it strengthens the resilience of interconnected and interdependent infrastructure systems. This, in turn, enhances the ability of society and the economy to absorb and recover from routine disruptions and emergencies. A robust telecommunications infrastructure ensures that not only citizens but also first responders or government remain connected even in the most extreme situations, ensuring public safety, maintaining economic stability and supporting effective disaster response and recovery efforts.

2. Study design

2.1. Our unified approach

The project employs a 3E approach—Explore, Evaluate and Execute—utilizing both top-down and bottom-up methodologies to tackle challenges across all phases of disaster. This approach facilitates a deep understanding of the interconnectedness and interdependencies among stakeholders while exploring global and local best practices. It also assesses the underlying disaster risks across various geographies and evaluates the coping capacity of existing systems. The detailed components of the approach are:



EXPLORE

- Stakeholder mapping and consultation
- Consolidate global and local knowledge (Desk review)
- Selection of three most vulnerable districts and blocks across five states
- Engage with stakeholders (Field consultations-FGD/KII)

EVALUATE

- GIS-based multi-hazard risk mapping of telecom infrastructure system
- Assess the need for strengthening disaster resilience across five dimensions
- Cost benefit analysis of selected resilience intervention

EXECUTE

- Develop DRRAF, recommendations and actionable roadmap
- Disseminate key findings to stakeholders (Workshop)

Explore

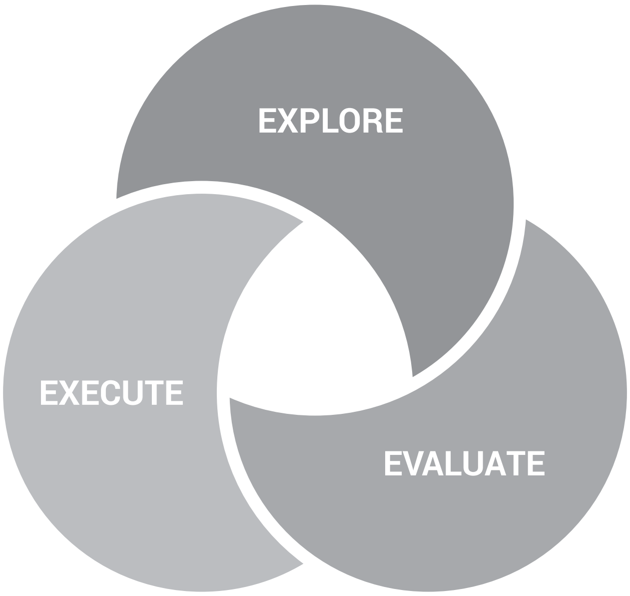
The project began with stakeholder mapping and developing a stakeholder engagement plan. A thorough review of secondary information was conducted across five domains: policy institutions and processes (PIP), technical planning and design, operation and maintenance, expertise, and financial arrangements and incentives. The team analysed historical disaster impact data, hazard information, and the readiness of telecommunications infrastructure to identify necessary enhancements for disaster resilience at both national and sub-national levels. Five states across different geographies (hill, coast, and plain) and three vulnerable districts from each of these states were selected for an in-depth study. Ground data was collected through surveys, key informant interviews (KII), and focus group discussions (FGDs) to capture challenges and existing practices.

Evaluate

A multi-hazard risk mapping at the national, state, district and block levels to assess the degree of exposure, vulnerability and risk associated with telecommunications infrastructure systems across the three miles: first, middle and last was conducted. This evaluation provided insights into the necessary level of preparedness, highlighting its benefits in terms of redundancy, flexibility, robustness, rapid response, resourcefulness, governance and overall responsiveness. These factors enable the infrastructure to withstand the impacts of future disasters. Additionally, this phase contributed key inputs for developing the Disaster Risk and Resilience Assessment Framework (DRRAF), along with recommendations and an actionable roadmap for the country and selected states.

Execute

The study's findings were developed into a framework designed to guide the sector in conducting disaster risk and resilience assessments. The aim was to prepare for future hazards by transitioning from the traditional linear approach to a system-scale approach. This new approach considers the interdependencies and interconnectedness across various geographies and types of telecommunications infrastructure. The recommendations and actionable roadmap will assist different stakeholders select the optimal resilience interventions and enhance preparedness, response and recovery efforts.



A

Explore

Chapter 3: The state of telecommunications sector, India

Chapter 4: Global insights and India's initiative towards disaster resilient telecommunications

B

Evaluate

Chapter 5: Multi-hazard risk mapping of telecommunications assets

C

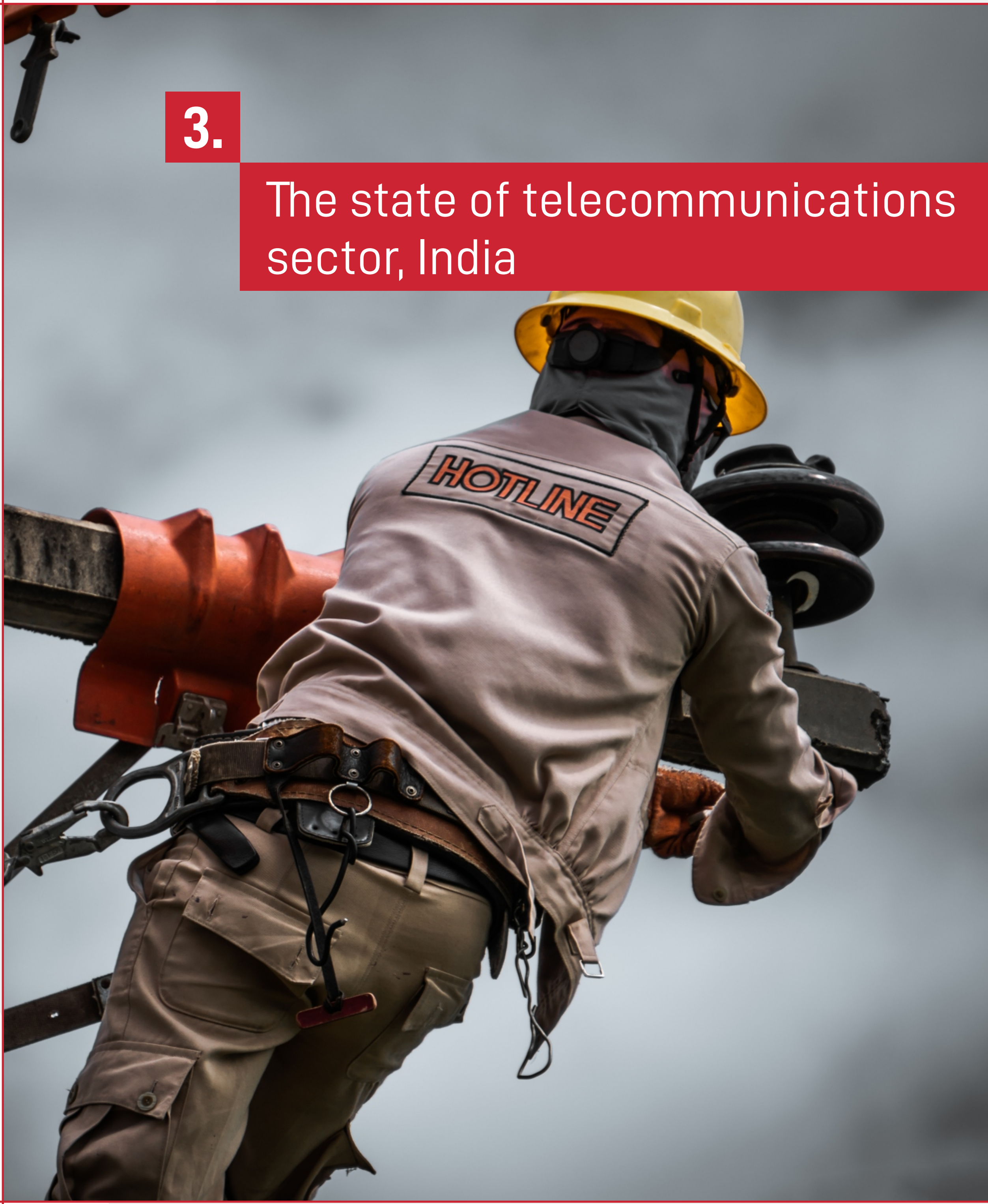
Execute

Chapter 6: Transforming Catastrophe into Continuity: A Disaster Resilience Framework

Chapter 7: Key recommendations

Chapter 8: Actionable roadmap for India and selected states

3. The state of telecommunications sector, India



3.1. Telecommunications infrastructure systems

The Indian telecommunication system is a vast and rapidly evolving network crucial to the country's economic growth and digital transformation. It encompasses diverse technologies, including landlines, mobile networks, satellite communications and internet services, essential for global connectivity. The sector has witnessed significant growth, driven by advancements such as 5G, the Internet of Things (IoT) and cloud computing. These innovations have enhanced global connectivity, reduced communication costs and accelerated the digitalization of various industries. The widespread adoption of smartphones and increased internet accessibility have spurred demand, while regulatory reforms have fostered competition and innovation. Supported by liberalization policies, substantial foreign investments and advancements in mobile technology, India has developed one of the world's largest telecommunications markets. Furthermore, the government is strongly focused on expanding internet access and enhancing mobile connectivity, paving the way for continued innovation and growth, especially with the emergence of 5G technology.

The advent of 6G technology, along with the broader integration of AI and space technology, is transforming the sectoral landscape by decreasing long tower infrastructure requirements and expanding geographical spread. Satellite communication, especially through Low Earth Orbit (LEO) satellite constellations, will soon provide seamless connectivity in remote areas. Furthermore, advancements in network virtualization, software-defined networking (SDN), and edge computing are set to enhance service application performance in the near future.

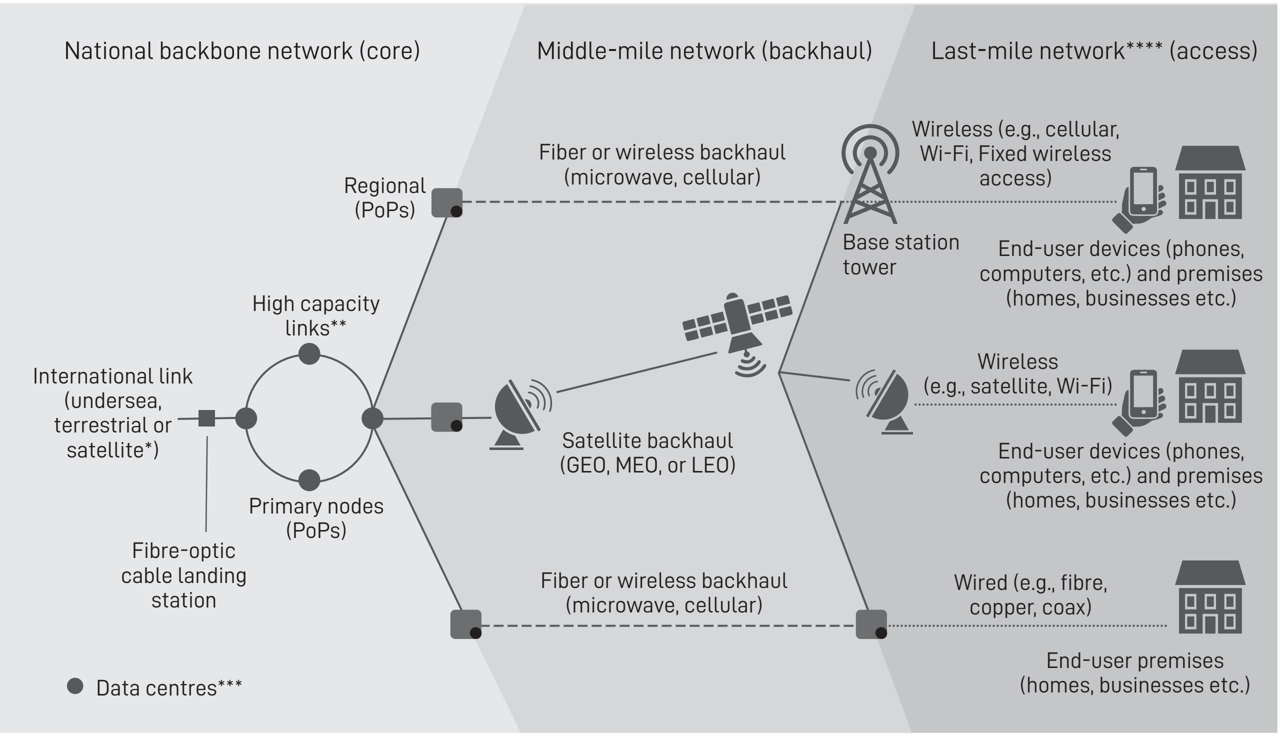


Figure 3.1: Schematic diagram of telecommunication network

Note:

* In a few country cases, satellite continues to be the main, or only, source of international connectivity.

** These are predominantly fibre-optic cables (terrestrial and undersea), but in a few cases, national backbone networks utilize wireless microwave and satellite.

*** Data centres can be placed in various parts of the network, depending on the need to aggregate data (such as in core networks) or place data as close to end users as possible (such as in middle-mile and last-mile networks).

**** The technologies listed for the last mile are not exhaustive.

Figure 3.1[18] shows the schematic diagram of the telecommunications network across the country. The telecommunications infrastructure in India can be categorized based on different aspects of the communication network. The following sections will discuss the main categories of telecommunications infrastructure systems.

3.1.1. Core network infrastructure

- **Switching centres:** A switch centre establishes a communication path on demand and disconnects it when it is no longer needed.
- **Data centres:** A Data centres: A Data Centre (DC) is a physical facility used for storing and managing applications and data. These centres house cloud servers that store digital data and applications, allowing users to access them via broadband connectivity. India has rapidly emerged as a thriving DC hub, driven by its large and expanding Internet user base, the exponential growth of data, and the creation of a supportive environment fostered by the government's Digital India initiative..

Table 3.1 presents the distribution of DCs across major cities in India.

Table 3.1 : Data centres in top seven cities in India

Location	No. of DCs	Capacity installed (in MW)
Delhi-NCR	22	72
Bengaluru	20	162
Chennai	13	57
Pune	6	32
Mumbai	33	289
Kolkata	6	5
Hyderabad	11	38
Total	**133**	**655**

Source: Recommendations on Regulatory Framework for Promoting Data Economy Through Establishment of Data Centres, Content Delivery Networks, and Interconnect Exchanges in India, TRAI[19]

Table 3.1 highlights that Mumbai and Bengaluru have the highest average capacity per DC, suggesting that their facilities are both larger in size and more power intensive. Conversely, Kolkata has the lowest average capacity, indicating smaller or less power-demanding operations. Understanding these disparities is essential for strategic DC investment and expansion planning. Table 3.2 presents states with a significant DC presence, as well as those that are trailing behind.

Table 3.2 : Status of DCs across Indian states

States with established DCs	States lagging in DCs
Gujarat	Arunachal Pradesh
Kerala	Assam
Rajasthan	Bihar
Maharashtra	Chhattisgarh
Karnataka	Goa
Tamil Nadu	Himachal Pradesh
Haryana	Jharkhand
Andhra Pradesh	Manipur
Haryana	Meghalaya
Telangana	Mizoram
Madhya Pradesh	Nagaland
West Bengal	Odisha
Uttar Pradesh	Sikkim
Punjab	Tripura
Delhi	Uttarakhand

Source: Recommendations on Regulatory Framework for Promoting Data Economy Through Establishment of Data Centres, Content Delivery Networks, and Interconnect Exchanges in India, TRAI

The government in India has proposed formulating a scheme to incentivize investments to set up hyper-scale DCs in India and boost the capacity of the existing DC ecosystem.

- **Internet exchange points (IXPs):** These are common grounds of internet protocol (IP) networking, allowing participant internet service providers (ISPs) to exchange data. It helps improve speed, reduce latency, and decrease the cost of data exchange between ISPs.

3.1.2. Transmission infrastructure

- **Optical fibre networks:** Data communication networks constructed using optical fibre technology. They employ optical fibre cables (OFCs) as the main communication medium to transmit data by converting it into light pulses that travel between sender and receiver nodes.
- **Microwave links:** A wireless communication technology that uses microwave frequency ranges to transmit information between two fixed locations on Earth, enabling point-to-point communication, especially in remote or far-flung areas.
- **Submarine cable and landing station:** Submarine cables (SMCs)[20] and cable landing stations (CLSs) are essential for global telecommunications, forming the backbone of international data transfer by digitally connecting countries through cables laid on the ocean floor. These cables carry about 99 percent of international internet traffic. They consist of a 'Dry Plant', including the CLS on land, and a 'Wet Plant', which comprises the SMCs and associated equipment on the seabed. SMCs have evolved significantly, increasing from four pairs in the early 2000s to as many as 24 fibre pairs today. Currently, there are 486 cable systems spanning over 1.3 million km worldwide. As per a 2022 TRAI report, India has about 17 SMCs terminating at 14 distinct CLS locations, with the majority landing in Mumbai and Chennai. Figure 3.2 gives the SMC map of the world while Figure 3.3[21] presents the Indian Submarine Network for domestic traffic. It is important to note that laying SMCs in Indian territorial waters is permitted only up to 12 nautical miles.

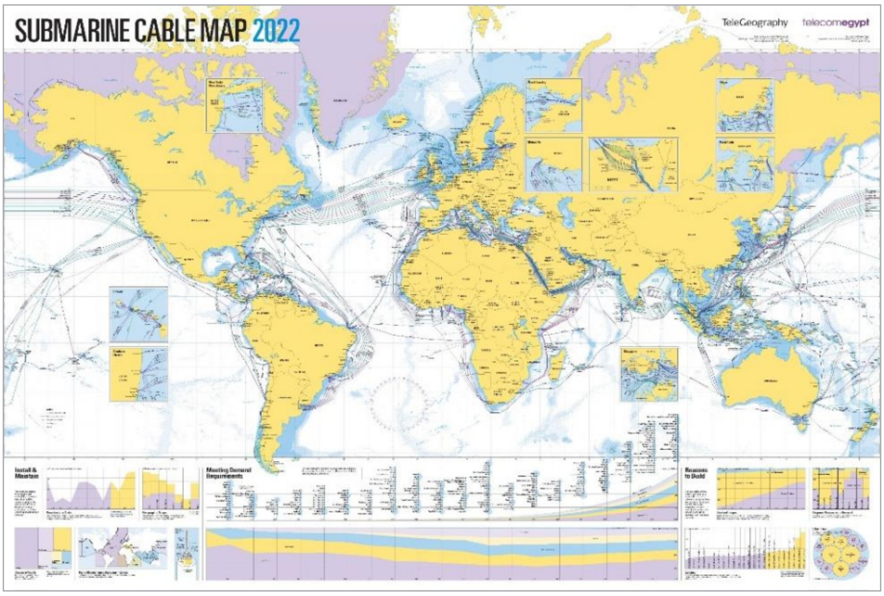


Figure 3.2: Submarine cable map (Worldwide, 2022)
(Source: TeleGeography)

Figure 3.3: Indian submarine cable network for domestic traffic

Currently, India depends on foreign vessels for repairs to faults in SMCs. This reliance leads to significant delays in addressing faults. Table 3.3 presents a snapshot of SMC repair activity for Indian cables and the time taken to repair.

Table 3.3 : Details on the SMC repair arrangement for Indian cables

Vessel base location	No. of vessels	Vessel flag	Area of operation	Average response time in Indian waters
Hamirayah (UAE) and Salalah (Oman)	5	Non-Indian	Middle East (Egypt) to Andaman Nicobar Islands (India)	3-5 months
Singapore and Indonesia	3	Non-Indian	South-East Asia and Indian Ocean region	4-5 months

- **Cable Landing Stations:** CLSs are essential for terminating submarine fibre optic cables and connecting India to the global internet backbone which drives economic growth and the country's strategic capabilities. They play a critical role in managing international internet traffic and providing redundancy in case of cable faults or disruptions. However, they face many challenges posed bylike physical threats and cybersecurity threatsattacks, intricate regulatory and compliance issues, high maintenance and upgrade costs for ageing infrastructure, environmental concerns, and operational difficulties, including maintenance and redundancy, . contribute to the overall challenge andThis makes it essential for a coordinated effort by the stakeholders to ensure robust and reliable international connectivity that drives economic growth, and enhances the country's strategic capabilities.
- **Manhole:** In the telecommunications sector, a "manhole" is an underground access point that allows technicians to reach and manage the network infrastructure, such as cables, conduits, and other equipment. It provides a safe and accessible space for workers to perform tasks like cable splicing, testing, and repairs without disrupting surface activities. The interconnection between manholes and an Multi Carrier Channel (MCH) involves the infrastructure that links them. Cables running from the MCH can pass through various manholes as they extend throughout the network. These manholes provide crucial access points for managing and maintaining the connections that lead to and from the MCH, ensuring efficient network operation and ease of troubleshooting or upgrading the infrastructure as needed.

3.1.3.Access network infrastructure

- **Telecommunication towers:** Telecommunication towers are critical infrastructure that facilitate wireless communication by supporting antennas and other equipment. Various types of towers are employed in mobile networks based on their suitability for the installation site, the antenna load they need to support and the terrain of the area. These towers can be classified into several types based on their design, structure and the type of installation.[22] Understanding these classifications helps in optimizing network coverage, reducing costs and minimizing hazard impacts. As of 1 December 2024, there are 814,040 telecommunication towers of different types installed across the country.[23]

Types of towers based on design/structure

The classification of telecommunication towers based on their design and structure are as follows:

- **Lattice structure:** Lattice towers, often referred to as "self-supporting towers," are structures that stand independently, either on the ground or atop a building. These versatile towers are constructed using triangular and rectangular steel bases, making them adaptable to various requirements. They are designed for easy modifications and are particularly suitable for supporting dish antennas, multiple panels, and other essential attachments for network and telephone towers. Lattice towers are generally more cost-effective to construct and maintain than solid towers. Their open design enhances wind resistance and can be built in different sizes to meet specific needs.
- **Guyed towers:** Guyed towers are typically secured with guy wires in three directions. These towers are considerably lighter than self-supporting towers, but they do require a substantial amount of open space for anchoring the guy wires. Further, there are additional restrictions when it comes to mounting dish antennas on these towers, including the need for large anchor blocks to secure the guy wires.
- **Tubular tower:** Tubular steel towers, also known as mobile tower structures, are designed for high-load applications. Built with seamless tubular sections, these towers offer exceptional strength, making them crucial for enhancing network reliability. They are strategically installed in remote areas on the outskirts of cities, helping to expand network coverage and enhance seamless connectivity. These structures play a crucial role in delivering seamless and reliable telecommunication service, catering to the needs of both urban and rural areas.
- **Monopole:** A monopole tower is a single, self-supporting structure commonly used in urban areas, especially on the rooftops of high-rise buildings. These are designed to accommodate a limited number of antennas and typically stand less than 9 meters tall. These towers are particularly advantageous in densely populated areas where space is scarce. Their smaller footprint compared to traditional lattice towers allows for efficient integration into the urban environment, minimizing visual impact while still delivering reliable communication services. The streamlined, tubular design not only enhances aesthetic appeal but also meets the requirements of areas with stringent height or space restrictions. This makes monopole towers an effective solution for telecommunications in dense habitation.
- **Reinforced concrete towers:** The concrete towers offer higher resistance to strong winds; however, these are expensive to build and install.
- **Angular towers:** Angular towers are 3-legged steel structures characterized by their triangular shape, with three vertical legs, or columns, connected at the top. These towers offer several benefits, making them a popular choice for various telecommunication applications. They are cost-effective, serving as an affordable solution for small towns with light load requirements. Their design provides exceptional support and stability, enabling them to withstand harsh weather conditions, and the space efficient design allows angular towers to be installed in limited spaces, making them a versatile option for urban environments.

Based on installation type, telecommunication towers are further categorized into:

- **Ground-based towers** – Ground-based towers are known for their sturdiness. They are designed with a high-load bearing capacity, supporting up to 12-panel antennas and three 0.6-metre-diameter microwave dish antennas. Their height ranges from 30 to 200 meters, providing essential vertical reach for optimal signal transmission. Additionally, these structures feature a sturdy foundation, ensuring superior stability and reliability when mounting communication equipment and antennas.

- **Rooftop towers –** Rooftop towers are installed on the rooftops of high-rise buildings. Their height varies from 9 meters to 30 meters. It features elevated columns and tie beams, allowing it to blend seamlessly with the architectural landscape. Hence, they offer an alternative for urban and modern spaces. One of their standout features is the ease of installation; these towers can be set up quickly and require minimal space and foundation work. This not only simplifies the installation process but also makes them a cost-effective option.

- **Telecommunication subscribers, and tele-density:** India has 1.2 billion (120 crore) telephone subscribers, as of 30 June 2024. Over the past decade, the total number of telephone subscribers in India has grown by 21%. Specifically, urban subscribers have increased by 15%, rural subscribers by 29%, wireless subscribers by 21%, and wireline subscribers by 33%. Table 3.4 presents the urban and rural tele-density of wireless and wireline subscribers across the country over the past five years.

Table 3.4 : Tele-density urban and rural (2020-24)

Particulars	2024		2023		2022		2021		2020	
	Wireless	Wireline	Wireless	Wireline	Wireless	Wireline	Wireless	Wireline	Wireless	Wireline
Urban subscriber (million)	633.44	29.12	627.13	25.59	627.12	22.26	641.48	19.7	629.67	18.24
Urban tele-density (%)	127.88	5.88	128.76	5.25	131.18	4.66	135.86	4.17	134.44	3.89
Rural subscriber (million)	525.05	2.72	515.89	2.14	518.13	1.95	535.36	1.96	524.11	1.81
Rural tele-density (%)	58.26	0.30	57.44	0.24	57.91	0.22	60.00	0.22	58.85	0.20

- **Base transceiver stations:** These devices facilitate mobile communication by connecting mobile devices to the network. They send and receive radio signals from mobile devices and convert them to digital data. This digital information is then routed through the network to other terminals in the network or to the internet.

- **Fixed-line networks:** These are traditional infrastructure used for landline telephone and digital subscriber line (DSL) services. Fixed lines are distinct from the mobile phone network, where end-users are connected to the network via wireless transmission technologies. The following sub-points give further details of fixed-line networks for the Indian telecommunications sector.

  - **State-wise PCOs details:** Data from government-owned telecommunications service providers (TSPs) indicate a significant decline in the number of public call offices (PCOs) across India. The number of PCOs decreased from 42,135 in 2023 to 20,652 in 2024, reflecting an approximate 51 percent reduction. The steepest declines were observed in regions such as Tamil Nadu (including Chennai), Mumbai, Andhra Pradesh and Karnataka, while smaller decreases were observed in Odisha, West Bengal and Himachal Pradesh. This trend is likely driven by technological advancements and the widespread adoption of mobile phones and internet services, which have rendered PCOs increasingly obsolete. The reduction in PCOs could affect access to telecommunications services in remote or rural areas, potentially widening the digital divide for populations that still depend on these services. Refer to Table 3.5.

Table 3.5 : Government-owned TSP PCOs across India as of March 2024

Name of telecom service area	Number of PCOs as on 31.03.2024
Andhra Pradesh	2,205
Assam	374
Bihar	29
Delhi-NCR	1,097
Gujarat	1,306
Haryana	52
Himachal Pradesh	5
Jammu and Kashmir	81
Karnataka	546
Kerala	2,153
Kolkata	506
Madhya Pradesh	478
Maharashtra	1,241
Mumbai	3,860
Northeast	155
Odisha	0
Punjab	281
	284
Rajasthan	51
Tamil Nadu including Chennai	4,921
Uttar Pradesh - East	525
Uttar Pradesh - West	489
West Bengal	13
Total	**20,652**

Source: The Indian Telecom Services Performance Indicators, January–March 2024[24]

- **Village public telephones:** As of 2024, India has 68,606 village public telephones (VPTs). The highest concentration are in West Bengal, with 11,970 VPTs; Madhya Pradesh, with 10,100 VPTs; and Maharashtra, with 7,846 VPTs. Other significant regions include Bihar, with 6,114 VPTs; Andhra Pradesh, with 2,896 VPTs; and Tamil Nadu (including Chennai), with 5,478 VPTs. However, regions such as Delhi, Mumbai and Rajasthan have reported no availability of VPTs. This information highlights the crucial role of VPTs in maintaining connectivity in rural India, where they continue to be an essential component of the communication infrastructure. See Table 3.6.

Table 3.6 : Service area and operator-wise details of village public telephones in India

Name of circle/service area	Number of VPTs as on 31.03.2024
Andhra Pradesh	2,896
Assam	105
Bihar	6,114
Delhi-NCR	-
Gujarat	5,278
Haryana	462
Himachal Pradesh	1,875
Jammu and Kashmir	810
Karnataka	3,656
Kerala	331
Kolkata	130
Madhya Pradesh	10,100
Maharashtra	7,846
Mumbai	-
Northeast	1,182
Odisha	1,554
Punjab	4,493
Rajasthan	-
Tamil Nadu including Chennai	5,478
Uttar Pradesh - East	568
Uttar Pradesh - West	3,758
West Bengal	11,970
Total	**68,606**

Source: The Indian Telecom Services Performance Indicators, January–March 2024

3.1.4. Wireless infrastructure

- **Mobile networks:** A mobile network, also known as a wireless network, transmits communication in the form of radio waves between users. It consists of base stations that cover specific areas, referred to as 'cells'. When these cells are interconnected, they provide radio coverage over a broad geographic region. The following is the description of various mobile network technologies:
  - **2G:** India currently has between 250 and 300 million 2G users, and it is expected that 2G technology will remain prevalent in the country for the foreseeable future. This is mainly because a significant portion of the population still relies on 2G, particularly those who cannot afford smartphones. Industry data reveals that approximately 50 million 2G phones are sold annually, with over 500,000 2G base tower stations nationwide.[25]

- **4G:** Based on long-term evolution (LTE) and LTE-Advanced standards, 4G technology has transformed mobile internet connectivity by enabling high-speed data transfer, video streaming and online gaming. India has witnessed a rapid adoption of 4G, making it a key driver of the digital economy.
- **5G:** India is currently expanding its 5G networks, which are expected to offer significantly faster speeds, reduced latency, and the capability to connect a vast number of devices simultaneously. This technology will bring transformative changes across various sectors, including healthcare, manufacturing, and transportation. Currently, there are 450,000 base transceiver stations equipped with 5G technology across the country. By the end of 2027, 5G is expected to make up nearly 40 percent of mobile subscriptions, totalling around 500 million users. This marks a significant increase from 110 to 120 million 5G users recorded in 2023.

- **Internet and broadband subscribers:** India currently has 950 million internet subscribers and 920 million broadband subscribers. Over the past decade (from 2014-15 to 2023-24), the number of internet subscribers has surged by 216 percent, while broadband subscribers have experienced an extraordinary increase of 832%. During this same period, urban internet subscriptions grew by 193 percent, whereas rural internet subscriptions saw a significant rise of 256 percent.
- **Wi-Fi networks:** Wi-Fi is a wireless networking technology that allows users to connect to the internet without cables; it is commonly used in offices and homes.

Satellite communication

In 2022, India implemented major reforms[26] in satellite communication (SATCOM) to enhance its ecosystem[25]. These reforms are part of a larger mission to position India as a global hub for SATCOM services and to support the Digital India initiative. The key aspects of these reforms include:

- **Focus on rural and remote connectivity**
    - **Financial relief for service providers:** The removal of network operation and control section (NOCC) charges, previously set at INR 21 lakhs (INR 2.1 million per transponder (36 MHz) per annum for telecommunications service licensees using space segments, alleviates financial burdens. Additionally, the elimination of mandatory performance verification testing (MPVT) charges, which were INR 6,000 per antenna, along with the waiver of the terminal annual license fee of INR 10,000 for M2M/IoT devices for captive very small aperture terminal (VSAT) licensees, will enable service providers to offer more affordable services. These measures encourage further investment in network improvements and facilitate extending connectivity to remote and challenging terrains via satellite.
    - **Encouragement of technological advancement:** By expanding the scope of licenses to include satellite-based M2M/IoT devices, the reforms pave the way for integrating satellite-based IoT solutions in sectors such as logistics, industrial automation, railways, agriculture, and disaster management. As a result, this opens up enormous potential for IoT/M2M applications for the public.
    - **Expansion of 4G/5G services:** Using movable platforms like boats, trains, airplanes, and other vehicles, the newer generation of low earth orbit (LEO) satellites addresses the latency limitations of geosynchronous earth orbit networks, providing the higher bandwidth necessary for backhauling 4G/5G mobile services.

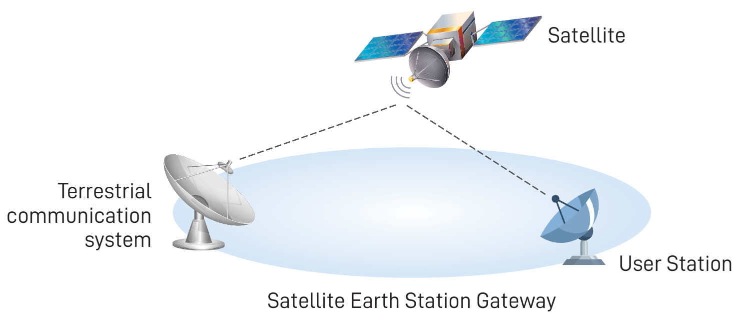


Figure 3.4: Satellite Communication Systems
(Source: TRAI)

Figure 3.4 illustrates the three key components of a typical SATCOM system: the satellite, the satellite earth station gateway (SESG) and the user station. The SESG, also known as the 'Gateway Hub', bridges the space-based communication network and the terrestrial communication network. Satellites operating in geostationary earth orbit (GEO), medium earth orbit (MEO) and LEO each have different levels of latency, which are influenced by their varying altitudes.

Table 3.7 provides a comparative analysis of GEO, MEO and LEO satellites.

Table 3.7 : GEO, MEO and LEO satellite characteristics

Satellite category	Altitude	Latency (round trip) in milliseconds	Average response time in Indian waters
GEO	35,786 km (22236.3 miles)	477 milliseconds	15 to 20
MEO	8,000 to 20,000 km (4970.9 - 12427.4 miles)	27 to 477 milliseconds	10 to 15
LEO	400 to 2,000 km (248.5 - 1242.7 miles)	2 to 27 milliseconds	5 to 10

Source: Consultation Paper on Terms and Conditions for the Assignment of Spectrum for Certain Satellite-Based Commercial Communication Services, TRAI[27]

Many SATCOM systems now use high-throughput satellites (HTSs). Initially, these systems relied on geostationary orbit (GSO) satellites. However, GSO satellites can experience round-trip propagation delays that exceed 500 milliseconds, which can be problematic for many digital connectivity applications. Consequently, there is a growing shift towards using MEO and LEO satellites in HTS systems. These satellites operate at altitudes as low as 400 km (248.5 miles), offering significantly shorter delays of as brief as 2 milliseconds.

Earth station

India has established a comprehensive network of earth stations operated by various entities, including ISRO, BSNL and private telecommunication operators. These stations play a critical role in maintaining robust SATCOM links and serve a variety of functions, such as broadcasting (e.g., direct-to-home or DTH services), providing internet access (particularly in rural and remote areas) and delivering telephone and data services (such as those for banking and meteorology). These facilities are vital for national security, disaster management and connectivity in geographically challenging regions. Table 3.8 provides information on the status of earth stations in India.

Table 3.8 : Status of earth stations in India

Type of earth stations	Locations
Satellite Earth Stations	Dehradun
Telecommunication Earth Stations	Metro cities and major regional centres across India
VSAT (Very Small Aperture Terminal) Earth Stations	Metro cities and major regional centres across India
Tracking, Telemetry and Command (TT&C) Earth Stations	Hyderabad, Bangalore, Lucknow, Port Blair, Thiruvananthapuram, Sriharikota, Hassan and Bhopal
Broadcasting Satellite Service (BSS) Earth Stations	Metro cities
Maritime and Aeronautical Earth Stations	Coastal cities and major ports

3.1.5. Support infrastructure

- **Power supply systems:** It is an integrated network of electrical components designed to supply (generate), transmit and consume electric power to various facilities and equipment.
- **Cooling systems:** Mechanisms are necessary for regulating ideal temperatures in DCs and network devices. The primary function of a cooling system is to maintain an optimal temperature by removing excess heat from a machine, engine, or environment.

3.1.6. Broadcast infrastructure

- **Radio and television towers:** These structures are designed to support antennas used for telecommunications and broadcasting, including television. They transmit signals over long distances, ensuring clear reception for radio and television audiences. Their height and strategic placement improve signal reach and quality.
- **Broadband technologies:**
  - **Fibre optics:** Fibre optic cables transmit data using light pulses that travel through thin glass fibres. They technology allows significantly faster speeds and higher bandwidth than traditional copper cables. In India, substantial investments are being made to expand the fibre optic network, spearheaded by initiatives such as BharatNet. These efforts aim to provide high-speed internet access to rural and remote areas[28] and are part of a broader strategy to enhance digital connectivity across the country.

Table 3.9 : Year-wise optical fibre-based connectivity

Year	Connection (in million)
February-18	17.7
February-19	18.2
February-21	22.3
February-22	26.6
February-23	32.8
February-24	39.5

BharatNet

Under the BharatNet project, broadband connectivity has been extended to 214,000-gram panchayats. As of 31 August 2024, a total of 690,000 km (428746.1 miles) of OFC has been laid, resulting in the establishment of 1.1 million high-speed broadband connections nationwide. provides a state-wise snapshot of gram panchayats connected to optical fibre as of the same date. Among all states and union territories, Uttar Pradesh has seen the installation of 100,000 km (62137.1 miles) of OFC laid. At the same time, Punjab leads the nation in high-speed broadband connectivity with 200,000 connections, the highest in the country.

Table 3.10 : State-wise no. of gram panchayats connected under BharatNet

State/UTs	Gram panchayat – connected (no.)	Optical fibre cable laid (km)	High-speed broadband (No.)
Andaman and Nicobar Islands	72	408	6,907
Andhra Pradesh	12,955	60,123	46,706
Arunachal Pradesh	1,108	1,519	13
Assam	1,507	4,877	5,489
Bihar	8,340	27,413	39,072
Chandigarh	12	19	0
Chhattisgarh	9,695	42,324	11,130
Delhi	0	0	0
Goa	0	0	0
Gujarat	14,316	55,418	119,987
Haryana	6,082	11,901	128,543
Himachal Pradesh	409	783	3,287
Jammu And Kashmir	1,099	860	9,396
Jharkhand	4,388	16,745	26,580
Karnataka	6,084	14,217	49,518
Kerala	978	830	177,704
Ladakh	193	0	0
Lakshadweep	9	0	0
Madhya Pradesh	17,850	67,768	53,633
Maharashtra	24,394	84,676	24,109
Manipur	1,469	634	1,107
Meghalaya	697	1,069	104
Mizoram	532	689	14
Nagaland	233	2,000	113
Odisha	6,785	32,373	10,495
Puducherry	98	93	3,707
Punjab	12,668	24,463	201,560
Rajasthan	8,776	30,662	47,946
Sikkim	35	942	43
Tamil Nadu	10,148	51,747	82
Telangana	10,824	34,262	20,557
Dadra and Nagar Haveli and Daman and Diu	38	112	104
Tripura	740	1,686	1,316
Uttar Pradesh	46,657	105,759	62,749
Uttarakhand	1,991	4,079	18,477
West Bengal	2,677	9,808	48,384

Source: DoT Dashboard

PM-WANI

The PM-WANI framework is designed to provide broadband access through public Wi-Fi hotspots, facilitating business operations and encouraging local ISPs to become Wi-Fi service providers. The Department of Telecommunications (DoT), Government of India, has approved that last-mile public Wi-Fi providers will not require a license or registration and will not be subject to fees. As of 30 June 2024, approximately 200,000 Wi-Fi hotspots have been installed under the PM-WANI scheme. However, this number falls short of the National Digital Communications Policy (NDCP) 2018 and the Bharat 6G Vision document.

Table 3.11 gives a snapshot of the state/union territory-wise PM-WANI hotspots installed on 5 February 2024. Of all the states/union territories, Delhi has the highest number of Wi-Fi installed (68,799), followed by Karnataka (20,192).

Table 3.11 : State/UT-wise PM-WANI hotspots installed

Name of telecom service area	Number of PCOs as on 31.03.2024
Andaman and Nicobar Islands	259
Andhra Pradesh	6,065
Arunachal Pradesh	1,016
Assam	882
Bihar	3,967
Chandigarh	257
Chhattisgarh	2,816
Delhi	68,799
Goa	422
Gujarat	4,162
Haryana	3,774
Himachal Pradesh	935
Jammu and Kashmir	1,020
Jharkhand	2,289
Karnataka	20,192
Kerala	4,930
Ladakh	601
Lakshadweep	1
Madhya Pradesh	16,322
Maharashtra	7,532
Manipur	19
Meghalaya	256
Mizoram	3
Nagaland	78
Odisha	2,892
Puducherry	89
Punjab	3,739
Rajasthan	2,913
Sikkim	13
Tamil Nadu	7,507
Telangana	4,239
Tripura	308
Uttar Pradesh	8,534
Uttarakhand	968
West Bengal	3,950

Source: DoT Dashboard

These categories help in understanding the various components that constitute the telecommunications infrastructure in India. Each component is vital in ensuring comprehensive connectivity and communication services across the country. Table 3.12 gives the primary telecommunications network value chain required, and the key technologies deployed for each mile.

Table 3.12 : Telecommunications network value chain

Network value chain segment	Applicable service category as per unified license (UL)	Primary telecommunications infrastructure	Technologies
First mile	• International Long Distance • Resale of International Leased Private Circuit (IPLC) • VSAT CUG	• Submarine cables and landing stations • Communication satellite and earth station	**Transmission technologies** • Synchronous Digital Hierarchy (SDH) • Dense Wavelength Division Multiplexing (DWDM) • Internet Protocol (IP) – Multi-Protocol Label Switching (MPLS) • Geostationary Orbit Satellites
Middle mile	• National Long Distance (NLD)	• Optical Fibre Cable (OFC) • nternet Exchange Points (IXP) • Data Centres • Mobile Switching Centres (MSC)	**Transmission technologies** • Synchronous Digital Hierarchy (SDH) • Dense Wavelength Division Multiplexing (DWDM) • Internet Protocol (IP) – Multi-Protocol Label Switching (MPLS) • Microwave Communication
Last mile	• Access service • Internet service • PMRTS • VSAT CUG • INSAT MSS-R	• Telecommunications towers and Cell on Wheels (CoW) • BTS • BSC/RNC • Microwave and OFC transmission nod es • HAM radio and walkie-talkie • ONT/OLT • Satellite pho nes	**Wireless technologies** • 2G,3G,4G,5G • Satellite communication • Wi-Fi/WiMAX **Wireline technologies** • Fibre to the home/office (FTTx) • Ethernet • Cable model • Digital Subscriber Line (DSL)

3.2. List of a few standards followed across the sector

Telecommunications infrastructure is governed by various technical standards and design principles to ensure interoperability, reliability, resilience and security across different regions and technologies. Table 3.13 provides a snapshot of a few technical standards that need adoption/revision.

Table 3.13 : Technical standards

Parameters	Standard reference	Standard body	Remarks
40-metre tower for cellular system can withstand wind speeds up to170 kmph	TEC 45080:2005[29]	Telecommunication Engineering Centre (TEC), India	The design code requires revision to adequately address the conditions in super cyclonic regions.
Roof top tower for cellular mobile systems (30/25/20/15/10 M Tower)	TEC 45140:2004	Telecommunication Engineering Centre (TEC), India	The design code currently only accounts for seismic impacts and does not address the combined effects of cyclones and earthquakes. It is important to revise this code, particularly for regions in the northeastern states and other Himalayan states, to ensure effective hazard mitigation.
BTS Shelter	TEC 35070:2011	Telecommunication Engineering Centre (TEC), India	For outdoor installation of BTS shelters, the survival wind speed should align with the site's wind zone as specified in IS 875 Part 3. However, the local wind zone maps across the country have not been consistently updated. Therefore, BTS shelters should be designed to withstand the maximum local wind impacts to ensure service reliability.
QoS Parameters for Voice Services: 'End-to-end QoS for voice over 4G mobile networks'	ITU-T Rec. G.1028 (06/2019)[30]	International Telecommunication Union (ITU)	The current LTE network supports asymmetric bandwidth, with upload speeds typically ranging from 1/4 to 1/8 of download speeds. The ITU recommends provisions for symmetric bandwidth to enhance Quality of Service (QoS) parameters.

Parameters	Standard reference	Standard body	Remarks
Standard for interface requirements for communication and broadcast networks for FSS/BSS	TEC 42012:2021	Telecommunication Engineering Centre (TEC)	The mandatory interface requirements apply to land-based mobile earth stations and VSATs communicating with geostationary satellites. However, these requirements do not explicitly address communication with polar satellites.
Revision of QoS improving latency	ITU recommendation – 1545.1	International Telecommunication Union (ITU)	Currently, latency for wireless connections exceeds 250 ms, while for wireline connections, it is over 120 ms. This must be improved to en sure interoperability with next-generation communication technologies, such as SATCOM through LEO satellites, which offer latency between 2 and 27 ms.
Interface for communication and broadcast networks	ITUT K10032	International Telecommunication Union (ITU)	Limited scaling up of SATCOM and broadcasting interface across the country. ITU suggests the wider adoption for establishing seamless communication during disaster.
Planning, construction and operation of data centres	EN 50600 European standard and TIA 942	European Standards[31]	Limited data centre in Tier 2 and 3 cities to provide disaster communication. Scale up data centres across the cities following the standard.
Code of practice for design loads (other than earthquakes) for buildings and structures. (Part 4) – snow load	IS:875 (1987)	Bureau of Indian Standard	The thickness of ice deposits is typically assumed to be between 3 and 10 mm, depending on the structure's location. However, this standard should be revised to account for the snowfall amounts in higher altitude regions of Himalayan states such as Ladakh, Uttarakhand and Arunachal Pradesh.

3.3. Key policy and guidance documents

The Indian telecommunications sector has undergone significant transformation in recent years, evolving from a government-controlled system into a liberalized market. It is now one of the largest and most dynamic telecommunications markets globally. To keep pace with technological advancements and emerging challenges, the sector's policies, standard operating procedures, and guidelines are continuously updated. This includes enhancing disaster resilience by prioritizing the development of robust infrastructure, creating redundant networks, and establishing emergency communication channels. These measures ensure that communication lifelines remain reliable and effective, even in times of adversity. The following sections present a brief overview of some recent policies and guidance documents.

National Digital Communications Policy, 2018

The National Digital Communications Policy (NDCP) of 2018 was established to create a strong digital communication infrastructure, foster digital inclusivity, and position India as a global leader in the telecommunications industry. The policy set ambitious targets for broadband penetration, spectrum management and technological innovation. By concentrating on these key areas, the NDCP sought to accelerate growth and improve efficiency within the sector, ensuring that digital connectivity extends to even the most remote regions of the country. This policy leverages the transformative potential of digital communication networks to achieve digital empowerment and enhance the well-being of India's citizens. The policy's missions include:

- **Connect India:** To establish a robust digital communications infrastructure to promote 'Broadband for All' as a catalyst for socio-economic development.
- **Propel India:** To harness emerging digital technologies such as 5G, AI, IoT, Cloud and Big Data to deliver future-ready products and services. This initiative aims to drive the fourth industrial revolution (Industry 4.0) by encouraging investment, innovation and intellectual property generation.
- **Secure India:** To protect citizens' interests and ensure India's digital sovereignty by focusing on individual autonomy, data ownership, privacy and security while acknowledging data as a critical economic resource.

The policy further guides setting up of the standards for the telecommunication system through.

1. Amendment in National Building Code (NBC) of India: Telecommunication installations and the associated cabling and in-building solutions should be implemented through an amendment in the NBC.
2. Wider adoption of environmental and safety standards enabling self-certification mechanism
3. Development of Standard Essential Patents (SEPs) in the field of digital communication technologies
4. Frame and enforce standard operating procedures to be followed during disasters/natural calamities
5. Development of security standards for equipment and devices

Telecommunications Act, 2023

The Telecommunications Act of 2023 consolidates various laws into a more streamlined legal structure, the act simplifies regulatory processes, encourages investment and fosters innovation. Key provisions include effective spectrum management, robust consumer protection and stringent cybersecurity measures to ensure data security and privacy, aligning with the proposed Personal Data Protection Bill. The act prioritizes digital inclusion, particularly in underserved areas, and emphasizes environmental sustainability by mandating eco-friendly practices in telecommunications operations. This aims to position India for resilient growth, technological advancement and global leadership in the digital economy.

The Central Government in the interest of national security may issue directions with respect to:

1. Standards applicable to manufacturing, import and distribution of telecommunication equipment
2. Standards to be adopted by authorized entities

Sub-section (4) of section 22 of the Act mentions the implementation of standards, security practices, and upgradations of critical telecommunication infrastructure.

3.4. Licensing and spectrum management

License landscape and spectrum management

The DoT issues licenses to service providers to provide specific services based on the nationwide/Licensed Service Area (LSA)/secondary switching area (SSA). Under the unified license (UL), the DoT issues licenses for the services shown below.

211 Access Service Licenses

2627 ISP Licenses

55 National Long-Distance Licenses

35 International Long Distance (ILD) Licenses

09 Very Small Aperture Terminal (VSAT) Licenses

Table 3.14 represents the brief details of various licensing categories.

Table 3.14 : License landscape

License category	Detail
Access service	The access services are provided LSA-wise. The primary access services that shall be provided are as follows: • Collection, carriage, transmission, and delivery of voice and/or non-voice messages • Internet telephony • Internet services, including IPTV. • Broadband services and triple play, i.e., voice, video and data The access services shall be provided through wireline and/or wireless media.
Internet service	Internet services are granted for three distinct categories: • Category A: License to provide nationwide internet services • Category B: License to provide internet services for each LSA • Category C: License to provide internet services in secondary switching area (SSA) within the LSA
National Long Distance (NLD) service	NLD services are provided nationwide. The licensee is authorized to carry inter-circle telecommunications traffic over its NLD network and offer leased circuits, virtual private networks (VPNs) and bandwidth to other operators.
International Long distance (ILD) service	ILD services will be provided nationwide only through NLD or access service providers. The ILD services shall carry switched bearer telecommunications traffic over international networks for connectivity. The licensee shall not provide services directly to subscribers, except for International Private Leased Circuits (IPLC), Closed User Groups (CUG), or ILD voice services via calling cards.

Spectrum management

Spectrum management in India involves implementing regulatory and technical strategies to enhance the efficient and dynamic use of radio frequencies. This approach aims to adapt to evolving technologies, shifting market demands and the need for optimized spectrum utilization. The allocation and management of spectrum in India are overseen by various key bodies and policies to ensure its effective usage across telecommunications and broadcasting services. Table 3.15 gives a snapshot of key regulatory bodies and their roles in governing spectrum allocation and management in India.

Table 3.15 : Key regulatory bodies governing spectrum management in India

Regulatory body	Roles
Department of Telecommunications (DoT)	The DoT is part of the Ministry of Communications and is responsible for India's overall policy, licensing and coordination of spectrum management.
Wireless Planning and Coordination (WPC) Wing	The WPC is a DoT unit directly responsible for frequency spectrum management, including licensing, frequency assignments and regulatory functions. WPC is divided into major sections, such as Licensing and Regulation (LR), New Technology Group (NTG), and the Standing Advisory Committee on Radio Frequency Allocation (SACFA). SACFA makes recommendations on major frequency allocation issues, formulation of the frequency allocation plan, recommendations on the various issues related to the International Telecommunication Union (ITU).
Telecom Regulatory Authority of India (TRAI)	TRAI is an independent regulator that makes recommendations on issues related to telecommunications services, including spectrum pricing, licensing conditions, and auction methodologies.

Table 3.16 provides information on different available spectrum band category and their respective frequency bands

Table 3.16 : Spectrum band categories of access spectrum

Spectrum band category	Short description of the category	Frequency band under the category
Category 1	Low bands	Sub-1 GHz bands i.e., 600 MHz, 700 MHz, 800 MHz, and 900 MHz bands
Category 2	Mid bands (FDD)	1800 MHz and 2100 MHz bands
Category 3	Mid bands (TDD)	2300 MHz, 2500 MHz, and 3300-3670 MHz bands
Category 4	High band	26 GHz and newly identified bands (37-37.5 GHz, 37.5-40 Hz, 42.5-43.5 GHz)

3.5. Institutional setup of Indian telecommunications sector

The telecommunications sector in India operates under the Ministry of Communications and is led by the DoT at the national level. The DoT is responsible for developing telecommunications policies, managing licensing and coordination, overseeing matters related to telegraphs, telephones and wireless data, facilitating international cooperation in telecommunications and promoting standardization and research and development (R&D). Additionally, the DoT encourages private investment in the telecommunications sector. The DoT enforces wireless regulations by monitoring transmissions nationwide. It is supported by regulatory bodies such as the Telecom Regulatory Authority of India (TRAI), the Telecom Dispute Settlement and Appellate Tribunal (TDSAT), the Telecommunication Engineering Centre (TEC) and the Controller General of Communication Accounts (CGCA). Additionally, it works with state offices like LSAs and public sector units such as BSNL and MTNL. Figure 3.5 shows the institutional setup of the Indian telecommunications sector.

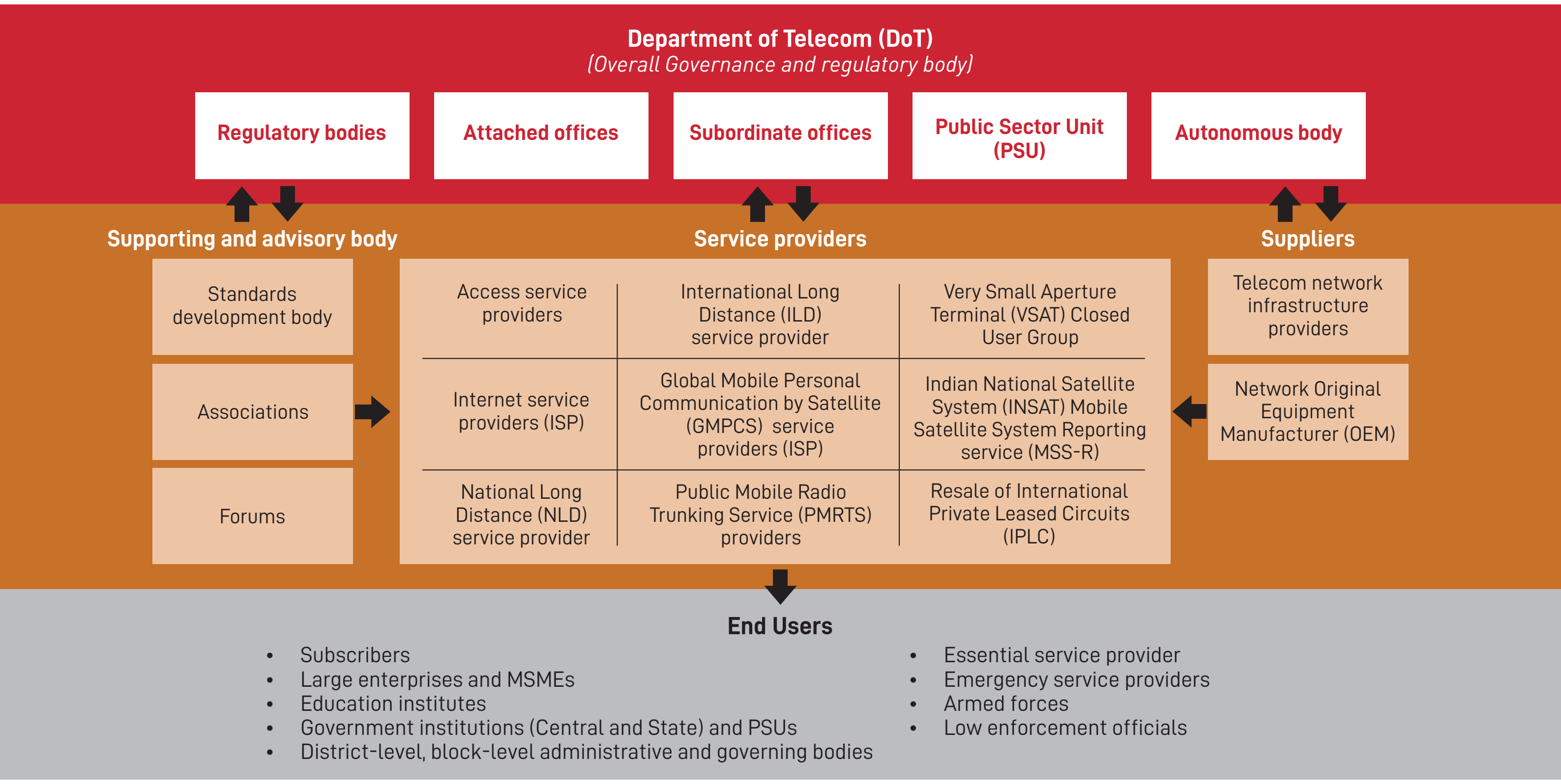


Figure 3.5: Telecommunication value chain

Administrative division

The telecommunications sector in India is administratively divided into 22 LSAs and 322 SSAs. This structure encompasses 28 states, eight union territories and five metropolitan cities. The sector offers a range of services, including voice, non-voice and internet, delivered via both wireline and wireless mediums. Based on the service type, the DoT grants licenses nationwide, LSA-wise, or SSA-wise, to service providers.

Governance and regulatory body: Department of Telecommunications

The DoT is the governing authority for telecommunications policy, licensing and coordination. It oversees telegraph, telephone and wireless data services. The DoT facilitates international cooperation in telecommunications, promotes standardization and encourages research and development (R&D) as well as private investment in the sector. Additionally, it manages radio communication frequencies and collaborates closely with international organizations. The DoT enforces wireless regulations by monitoring transmissions nationwide to ensure compliance.

The DoT is supported by various regulatory bodies, associated offices, subordinate offices, public sector units (PSU) and autonomous bodies. Details of these supporting bodies/offices are shown in Table 3.17.

Table 3.17 : Governance and regulatory body

Type	Name	Description
Statutory body	Telecom Regulatory Authority of India (TRAI)	TRAI is a telecom regulator that works to ensure and protect the interests of the customers and service providers. It has taken initiatives to promote the growth and development of the telecommunications sector, resulting in overall benefits to the consumers and industries in terms of choice of service, affordable tariff, better quality of services, etc.
Statutory body	Telecom Dispute Settlement Appellate Tribunal (TDSAT)	TDSAT regulates telecommunications services, adjudicates disputes and acts as an appellate body under TRAI and other regulations. Its primary goal is to protect the interests of service providers and consumers of the telecommunications, while also promoting and ensuring the orderly growth of the industry.
Attached office	Universal Service Obligation Fund (USOF)	USOF provides financial support for the provision of telecommunications services in remote and commercially unviable areas.
Attached office	Telecommunication Engineering Centre (TEC)	TEC supports standardization, testing and certification in the telecommunications and IT domains. It also advises the government on technological matters and ensures interoperability through standards/specifications. Additionally, it guarantees safety/security through testing/certification of telecommunication and information and communications technology (ICT) systems.
Attached office	Director General Telecom (DGT)	DGT, headed by an apex-level officer, monitors and controls the 36 field offices in 22 LSAs across India. The field offices in LSA play a vital role as an interface between the DoT and state governments for activities such as Right of Way (RoW) issues, smart cities and coverage improvement in uncovered areas, etc. The field offices in LSA also play a vital role as an interface between law enforcement agencies and telecommunications service providers in matters related to national security.

Type	Name	Description
Attached office	Controller General of Communication Accounts (CGCA)	CGCA provides support in five areas: - **Internal Audit** (IA) section responsible for IA of field units of the DoT and its attached offices, autonomous bodies, and DoT wings - **BA&IT section** responsible for O&M of Comprehensive Pension Management System (SAMPANN) and other activities related to pension, expenditure of field units, development and maintenance of website and software - **Revenue section** responsible for confirmation/amendment/extension/review of bank guarantee, release of PBG, monitoring of decentralized (non-access) licenses, monthly/progressive SUC collection for GSM/BWA/VSAT/CDMA - **Coordination and administration section** responsible for the monitoring of asset management activities by CCA offices, monitoring of court cases of field offices and maintenance of service book and fixation of pay, granting of leaves, tours and LTC, promotions and retirement - **Manuals and codification section** responsible for preparation of telecommunications accounts and finance manuals
Subordinate office	Wireless Planning and Coordination (WPC)	WPC serves as a nodal authority for planning, regulating, coordinating, authorizing and managing the radio frequency spectrum.
Subordinate office	Wireless Monitoring Organization (WMO)	The WMO provides support for monitoring/measuring radio spectrum usage to ensure interference-free radio communication in India. It is also responsible for the identification of frequency sub-bands for new services.
Subordinate office	National Telecommunications Institute for Policy Research, Innovation & Training (NTIPRIT)	NTIPRIT is a national telecommunications training institute of the DoT. It manages the training needs and focuses on policy research and innovation in the telecommunications sector.
Subordinate office	National Centre for Communications Security (NCCS)	NCCS establishes and operationalizes a framework of telecommunications security testing and certification. It has three divisions, i.e., Security Assurance Standards (SAS), Security Lab Recognition (SLR) and Security Certification (SC) division to manage the telecommunications security testing and certification needs.
Subordinate office	National Institute of Communication Finance (NICF)	NICF trains the Indian Post & Telecom Accounts and Finance Service (IP&TAFS) group.
Public sector unit (PSU)	Bharat Sanchar Nigam Limited (BSNL)	BSNL is owned by the Government of India and provides telecommunications services across India, excluding Mumbai and Delhi.
Public sector unit (PSU)	Mahanagar Telephone Nigam Limited (MTNL)	MTNL provides telecom services to Delhi, including NCR (towns of Ghaziabad, Faridabad, Noida, and Gurgaon) and Mumbai, including Navi Mumbai, Kalyan, and Dombivli.
Public sector unit (PSU)	Telecommunications Consultants India Limited (TCIL)	TCIL has diversified focus areas around cyber parks, intelligent buildings, cyber and smart cities, and system integrators in IT and telecommunications. It has operations in India and overseas.
Public sector unit (PSU)	ITI Limited	ITI manages the manufacturing and supply of telecommunications equipment to meet the needs of the telecommunications sector of India. It has manufacturing units in Srinagar, Naini, Rae Bareli, Mankapur and Palakkad.
Public sector unit (PSU)	Bharat Broadband Network Limited (BBNL)	BBNL is a Special Purpose Vehicle (SPV) set up to provide high-speed broadband connectivity to the rural parts of the country through the OFC network.
Autonomous body	The Centre for Development of Telematics (C-DOT)	C-DOT focuses on research and development activities to meet the upcoming needs of the telecommunications sector.

Support and advisory bodies

Numerous service-specific forums, associations, and standards development bodies offer support and guidance in various areas of the telecommunications sector. A list of these supporting and advisory bodies, along with relevant details, is shown in Table 3.18.

Table 3.18 : Support and advisory bodies

Type	Name	Description
Standards development	Telecommunications Standards Development Society, India (TSDSI)	TSDSI plays a vital role, both domestically and internationally, in meeting the national objectives of digital communications standards. The key objectives are as follows: - Developing, promoting, and standardizing India-specific telecommunications/information and communications technology (ICT) requirements and solutions - Taking Indian requirements to the global standards organization - Provide a platform to declare IP - Helping create standards-based manufacturing expertise - Providing guidance and leadership to developing countries
Association	Cellular Operators Association of India (COAI)	COAI interacts and provides a forum for discussion and exchange of ideas between the policymakers, regulators, financial institutions, technical bodies and service providers, who share a common interest in the development of the telecommunications sector in India.
Association	Digital Infrastructure Providers Associations (DIPA)	DIPA, erstwhile known as Tower and Infrastructure Providers Association (TAIPA), represents India's digital infrastructure industry that develops, builds, owns and operates the wireless infrastructure. The association interacts, discusses and deliberates with Indian government ministries, policymakers, financial institutions, regulators, etc., for knowledge sharing to promote healthy growth in the telecom sector.
Association	Internet Service Providers Association of India (ISPAI)	ISPAI interacts and provides a forum for discussion and exchange of ideas between the policymakers, regulators, financial institutions, technical bodies, and service providers, who share a common interest in the development of the internet and other services across India.
Association	Indian Space Association (ISpA)	ISpA is an apex, nonprofit industry body that works towards the successful exploration, collaboration and development of the public and private space industry in India. It focuses on policy advocacy, discussing and engaging with all stakeholders to exchange ideas and knowledge with all the agencies in the global space arena.

3.6. Existing financial mechanism

Universal Service Obligation Fund/Digital Bharat Nidhi

The Universal Service Obligation Fund (USOF), which has been renamed Digital Bharat Nidhi (DBN) in 2024, is committed to delivering high-quality and affordable mobile and digital services to rural and remote areas in India. Its mission is to ensure broad and non-discriminatory access to quality information and communications technology (ICT) services at affordable prices. Initially established under the Indian Telegraph Act of 1885, the fund's scope was expanded with the Telecommunications Act of 2023. This expansion includes support for innovation, research and development, commercialization of indigenous technologies, setting national standards, encouraging start-ups, and promoting sustainable and green technologies in the telecommunications sector. The primary aim of USOF/DBN is to bridge the digital divide, ensuring that rural and remote communities have access to information and knowledge, especially where ICT services are not commercially viable. Table 3.19 presents a few achievements under DBN.

Table 3.19 : Achievements under Digital Bharat Nidhi

Initiatives	Achievement
BHARATNET	• 2.14 lakhs (0.2 million) gram panchayats have been connected as on 13 January 2025 • 6.91 kms (4.29 miles) of total OFC laid • 11.35 lakhs (1.1 million) of fibre to the home (FTTH) has been commissioned • 1.05 lakhs (0.1 million) Wi-Fi hotspots have been installed at gram panchayats
Installation of Mobile Towers	• 294 mobile towers have been installed under 354 uncovered villages scheme • 2399 mobile towers have been commissioned in the North-east region? region • 1020 mobile towers have been installed under Left Wing Extremism (LWE) Phase-II • 192 mobile towers have been installed under 502 aspirational district scheme • 1935 mobile towers have been installed under the 7287 aspirational district scheme
Submarine OFC	• 8 islands connected under the Chennai-A&N island project • 2313 kms (1,437 miles) of submarine OFC laid under Chennai-A&N island project

Source: USOF dashboard, DoT [32]

3.7. Digital initiatives by Department of Telecommunications, India

The DoT has introduced major digital initiatives to enhance security, safety, and service quality for consumers and businesses alike. Below are summaries of key portals designed to offer valuable benefits to various stakeholders.

Sanchar Saathi

'Sanchar Saathi' is an initiative launched by the DoT. This initiative aims to bolster the security and safety of telecommunications subscribers and mitigate fraudulent activities within the telecommunications sector. Utilizing technology and data analytics, Sanchar Saathi addresses challenges such as fraud, identity theft and other security issues, thereby promoting a safer and more secure telecommunications environment.

The portal can be accessed here: www.sancharsaathi.gov.in

Saral Sanchar

'SARAL SANCHAR' (Simplified Application for Registration and Licenses) is an online portal introduced by the DoT under the Ministry of Communications, Government of India. Its primary goal is to streamline and simplify the process of obtaining various telecommunications licenses and registrations in India. The portal is designed to enhance transparency, minimize procedural complexities, and improve the overall efficiency of the licensing process. The key features and benefits of the SARAL SANCHAR portal include:

1. **Single window system:** SARAL SANCHAR provides a unified platform for applicants to submit applications for various telecom licenses and registrations. This integration minimizes the need for multiple submissions and interactions with different departments, simplifying the process and enhancing user-friendly.
2. **Online application and processing:** The entire workflow, from application submission to the issuance of licenses and registrations, is now conducted online. This digital method eliminates the need for physical paperwork and in-person visits, saving time and resources for both applicants and government officials.
3. **Real-time tracking:** Applicants can track the status of their applications in real-time via the portal, ensuring transparency and keeping them informed about the progress of their submissions.
4. **Multiple license types:** The portal accommodates a diverse range of licenses and registrations related to the telecommunications sector. This includes the Unified License-Virtual Network Operator, PM-WANI Registration, M2M Registrations, WPC Network and Non-Network, DPL/NDPL Licenses, WPC Import Licenses, WPC Experimental Licenses, Manufacturing and Demonstration Licenses, WPC - Certificate of Proficiency Licenses (HAM, RTR, GMDSS) and SACFA Clearances. This wide comprehensive coverage ensures efficient regulation of various telecom-related activities.

The portal can be accessed here: www.saralsanchar.gov.in

Tarang Sanchar

Tarang Sanchar is a web-based portal developed by the DoT. Its primary objective is to provide the public with detailed information about mobile tower installations and associated electromagnetic field (EMF) emissions, which are often a public concern. The key features and benefits of the Tarang Sanchar portal include:

1. **Information on mobile towers:** The portal offers comprehensive details about mobile tower locations across India. Users can search for and view information about nearby towers, including the telecom service providers operating them.
2. **EMF compliance:** Tarang Sanchar provides data on the compliance status of mobile towers with government-set EMF radiation norms. This ensures that the public is informed about the safety levels of EMF emissions from local towers.
3. **Public awareness and transparency:** The portal aims to enhance public awareness of EMF emissions and their potential health impacts. By making this information readily available, it addresses public concerns and misconceptions about the health risks associated with mobile towers.
4. **Complaint and feedback mechanism:** Tarang Sanchar offers a platform for the public to lodge complaints or provide feedback regarding mobile towers and EMF emissions, ensuring that public concerns are addressed promptly and effectively.
5. **Reports and certificates:** Users can access EMF test reports and compliance certificates for mobile towers. These reports, generated by accredited agencies, provide detailed measurements of EMF radiation levels, ensuring transparency and accountability.

The portal can be accessed here: www.tarangsanchar.gov.in

3.8. Interconnected infrastructure systems-power, road, and buildings

The telecommunications infrastructure system is highly dependent on the power infrastructure, as its service continuity is directly tied to a stable power supply. With the nationwide rollout of 5G technology and the increasing expansion of Roof Top Towers (RTTs), the sector has become more interconnected with building infrastructure. Additionally, road infrastructure is crucial for accessing telecommunications sites for various operational and maintenance activities. Consequently, any disruptions to these infrastructure systems can adversely affect the telecommunications infrastructure. Therefore, enhancing the resilience of these interconnected systems can bolster the overall resilience of the telecommunications infrastructure.

3.8.1. Key power sector policy/guideline

Need for resilient power supply for telecommunications infrastructure system

Telecommunications infrastructure is heavily reliant on the power infrastructure system. Limited access to power supply and disruptions in the supply can have cascading impacts on telecom services. This is equally true for telecom DCs, which require a consistent, reliable power supply to function effectively. Therefore, ensuring the resilience of the power infrastructure is crucial for the uninterrupted operation of telecommunications systems. By leveraging various power sector policies and initiatives, the telecommunications sector can leverage 24/7 energy access. Some of the key policies that can support better access to power supply for the telecommunications system are discussed here.

Revamped Distribution Sector Scheme

The Revamped Distribution Sector Scheme (RDSS) is designed to ensure a continuous 24/7 power supply for non-agricultural consumers. This scheme offers telecommunications operators the opportunity to access uninterrupted, reliable and green power supply for their assets, specifically in remote areas that experience frequent power outages due to ageing infrastructure. Furthermore, RDSS includes provisions for solarizing feeders under the KUSUM scheme. This allows telecom operators to access green energy and obtain a redundant power supply through solar power at their sites. The scheme also supports the modernization of distribution infrastructure, enhancing the reliability of power supply and providing an advantage to the telecom operators receiving uninterrupted power supply to their sites.

Mini-grid policy of the state

This policy promotes the decentralized generation of clean and green energy by utilizing renewable resources such as solar and biomass within the state. It allows telecom operators the opportunity to secure a reliable, clean power supply through local arrangements. The policy includes state-specific subsidies to encourage the local production of decentralized clean energy. This can be particularly beneficial for telecom operators, as it allows them to access power from local sources when the main power grid is disrupted during disasters at cheaper rates than grid supply.

Green energy open access regulations

Green energy open access regulations promote open access to electricity generated from renewable sources. The 'Long-term Green Energy Open Access' initiative allows telecom operators to secure both long- and short-term power access through clean sources through the open market. This regulation not only supports energy access and reliability but also ensures a more diversified and redundant power supply for telecom sites.

3.8.2. Building codes

Need for building codes on Indian telecommunications infrastructure system

India is experiencing a rapidly evolving digital landscape, with nearly 85% of data and 70% of voice traffic generated indoors commercial/public buildings.[33] The advancements in technologies like 4G and 5G, along with the integration of IoT devices, predominantly take place within buildings. To ensure these structures remain resilient during hazardous events, it is essential that their designs incorporate these technological elements from the ground up. Building codes serve as a blueprint for embedding connectivity into the very fabric of our built environment.

The National Building Code 2016 represents a pivotal advancement in acknowledging the essential role of robust digital infrastructure in contemporary construction. It establishes higher standards for ICT installations to meet the growing demand for increased bandwidth and faster internet speeds. Additionally, the Model Building Byelaws align with these technological advancements. However, while the National Building Code 2016 sets the foundation for a digitally connected future, actualizing these ambitions poses unique challenges. Bridging the digital divide necessitates updating codes, addressing the limitations of existing building infrastructure, raising awareness, and managing the complexities of rapid technological progress.

4. Global insights and India's initiatives towards disaster-resilient telecommunications

4.1. Tackling telecommunications challenges in disaster scenarios

4.1.1. Global good practices

The increasing frequency and intensity of extreme weather events—such as floods, storm surges, earthquakes, forest fires and cyclonic winds—are worsening the vulnerabilities of telecommunications infrastructure globally. The interconnected and interdependent nature of infrastructure amplifies these vulnerabilities, resulting in more unpredictable and severe consequences. This situation underscores the urgent need for disaster preparedness, response, and recovery efforts at a systemic level.

Many countries have adopted effective practices to enhance resilience against natural hazards. These measures include implementing early warning systems, conducting scenario-based risk and impact assessments, ensuring interoperability, maintaining power availability and fuel backup, and allocating financial resources. The following section highlights some of the successful initiatives undertaken by various countries to address key challenges posed by natural hazards, thereby building resilience.

Hazard: Cyclone/Hurricane/Typhoon

USA (Oct 2012)

Challenges	Solutions
Telecommunications service disruption	Provision of a dedicated network for first responder agencies and impacted individuals (FirstNet) with improved uplink throughput of up to 100%
	Provision of mobile cell site vehicle (SatCOLT-Satellite Cellular on Light Truck)

Puerto Rico (Sept 2017)

Challenges	Solutions
Telecommunications service disruption	Launch a fleet of high-altitude balloons equipped with LTE cellular transceivers into the stratosphere above Puerto Rico

Spain (Sept 2021)

Challenges	Solutions
Telecommunications service disruption	Deploy balloon network at an altitude of 20 km to provide LTE coverage in nearly 40 km of areas where CoWs cannot be deployed

Mozambique (Aug 2019)

Challenges	Solutions
Telecommunication service disruption in rural areas	Free Wi-Fi internet access points across all 154 districts

Hazard: Flood

Japan (July 2018)

Challenges	Solutions
Infrastructure inundation	Provision facilities with flood doors and waterproofed cable connection
Telecommunications service disruption	Provision of a flying base station known as HAPS, which will provide mobile services using solar-powered drones flying at altitudes of 11-15 miles (18-25 km). The coverage area would be 124 miles (200 km).

Philippines (Aug 2016)

Challenges	Solutions
Infrastructure inundation	Raise generators' height to prevent power outages
Fuel unavailability	Sites equipped with five days of emergency fuel backup

Thailand (Dec 2016)

Challenges	Solutions
Lack of risk financing	Specialized insurance policies tailored to the risks, covering physical damage to infrastructure
	Parametric insurance model triggering payouts based on pre-defined parameters

Hazard: Forest fire

Australia (Dec 2019)

Challenges	Solutions
Telecommunications service disruption	Mobile exchange on Wheels (MEOW).
Network unavailability	Provision of redundant backhaul.

Hazard: Landslide

Switzerland (Aug 2017)

Challenges	Solutions
High physical damage and financial loss	Provision to detect vibrations in the ground or other irregularities in real-time and trigger corresponding alerts

Hazard: Volcano

Tonga (Jan 2022)

Challenges	Solutions
Infrastructure damage and loss	Telecom carriers quickly reroute traffic through undamaged cables and satellite connections to restore partial connectivity.

Hazard: Earthquake

Japan (Mar 2011)

Challenges	Solutions
Poor service quality	Provision of packet duplication and decentralization to improve the reliability and latency of a network
Infrastructure damage and loss	Earthquake-resilient standards for all sites
Telecommunications service disruption	Ship with mobile base stations to provide connectivity in the coastal areas
Telecommunications service disruption	Network on a commercial car that can be powered on the car's battery in 15-20 min
Network blackout	During disaster, activation of long- and medium-range base stations to provide coverage up to 4-7 km

Turkey (Feb 2023)

Challenges	Solutions
Limited expertise	Capacity-building ramping based on disaster simulations
Infrastructure unavailability	Container-housed BTS, BSC and MSC for affected sites

Nepal (Nov 2023)

Challenges	Solutions
Infrastructure damage	Provision of dedicated conduit for laying of OFC

Bhutan (Sept 2011)

Challenges	Solutions
Limited Optical Fiber Cable network and internet exchange	• Set up an optical fibre cable (OFC) network across all 20 districts of Bhutan up to the gewog (village) level • Set up of Internet exchange point across districts for improvement in internet services

4.1.2. India's key initiatives at national level

Stakeholders in the Indian telecommunication sector encounter a variety of challenges across different regions, largely due to the varying degrees of impact from disasters experienced throughout the country. To address and mitigate the potential impacts of future disasters, several initiatives have been adopted at both national and sub-national levels. These initiatives aim not only to endure and recover swiftly from natural hazards but also to uphold critical communication services during emergencies. However, inherent vulnerabilities in the telecommunications assets and network infrastructure system can impair or prevent networks from functioning properly. There is an emerging consensus among network operators, associations, and authorities to enhance disaster resilience across the telecommunications system. Some of the key challenges faced by different stakeholders are mentioned in Table 4.1.

Table 4.1: Challenges faced by different stakeholders

Disaster impacts	Stakeholders affected
Limited connectivity	Consumers
Unavailability of emergency communication	First responders and local administration
Infrastructure damage and loss	Operators/service providers
Interruption in service delivery	Community
Impact on business continuity	Business owners

India is working towards achieving holistic multi-hazard resilience by focusing on various aspects such as technical planning, operations and maintenance, policy and institutional processes, financial arrangements, and the availability of expertise. This systemic approach ensures that all aspects of resilience are addressed, including technical, operational, policy, and financial levels. In addition to these measures, India also focuses on building capacity and raising awareness about disaster resilience. Training programmes and workshops are designed to equip telecommunications operators and other stakeholders with the knowledge and skills needed to implement effective resilience measures. Table 4.2 provides snapshots of key initiatives in the Indian telecommunications sector to strengthen the disaster resilience of the telecommunications infrastructure system.

Table 4.2 : Initiatives taken by DoT to strengthen telecommunications infrastructure system

Initiatives	Description
C-DOT signed an agreement with IIT, Roorkee and Mandi for 'Development of "Cell-Free" 6G Access Points' – July 2024[34]	This aligns with Bharat 6G's mission and aims to enhance user connectivity, eliminate dead zones, enhance signal strength and significantly boost data speeds even in densely populated areas.
The Telecommunications Act 2023: Ushering in a New Era of Connectivity – July 2024[35]	Amendments were made to the optimal utilization of spectrum, which provides a legal framework for efficient utilization of scarce spectrum through processes such as secondary assignment, sharing, trading, leasing and surrender of the spectrum. It also empowers the central government to establish an enforcement and monitoring mechanism for spectrum utilization.
C-DOT and Qualcomm sign MoU towards Atmanirbhar Bharat and driving Design and Make in India vision – March 2024[36]	This collaboration aims to strengthen the local Make in India domestic market by utilizing Qualcomm technologies and expertise in building innovative telecommunications solutions.
Regulations on Rating Framework for Digital Connectivity – September 2023[37]	This aims to implement a rating framework for buildings or areas for digital connectivity to improve the Quality of Services (QoS) inside buildings for a seamless consumer experience.
Bharat 6G vision: Design, develop and deploy 6G network technologies – March 2023[38]	This will play a key role in supporting the global sustainability goals, including India's objective to contribute towards climate emergencies. In addition, this will contribute to disaster management in the following areas: • Very large volume and tiny instant communications • Beyond best effort and high-precision communications and lossless networking and latency guarantee • Many nets (Satellite, MEC, Dense network) • Intelligent connected management and control functions, programmability and integrated sensing and communication

Some of the landmark disaster resilience initiatives taken by the DoT are as follows:

Public protection and disaster relief

Public protection and disaster relief (PPDR) communication systems are essential tools utilized by public safety organizations, including police, fire services, emergency medical services and disaster response teams, to perform their critical duties effectively. These systems are engineered to be robust, reliable and resilient, ensuring that first responders and emergency personnel can communicate seamlessly during both routine operations and crises. The key features of PPDR systems include:

- **Reliability and resilience:** Built to endure extreme conditions such as natural hazards and other emergencies, PPDR communication networks are designed to remain operational even when commercial networks fail. This ensures that critical communication channels remain open when they are needed the most.
- **Dedicated spectrum:** PPDR systems often operate on a dedicated radio frequency spectrum specifically allocated for public safety use. This allocation prevents public safety communications from being affected by congestion on commercial networks, guaranteeing clear and uninterrupted communication.
- **Interoperability:** A crucial requirement for PPDR systems is interoperability, which allows different agencies and organizations to communicate seamlessly. This capability is vital for coordinated response efforts during emergencies, enabling various teams to work together efficiently and effectively.
- **Extensive coverage:** PPDR systems provide comprehensive coverage, ensuring reliable communication in rural and remote areas and urban environments with high-rise buildings. This extensive reach ensures that first responders can maintain communication wherever their services are required.

Three types of technologies are used for PPDR based on data rates:

Narrowband:
Speed or bit rate up to 64 kbps, which is one voice channel in a radio system

Wideband:
Carry data rates of several hundred kilobits per second (e.g. in the range of 384-500 kbit/s)

Broadband:
Data rates in the range of 1-100 Mbit/s

The classification of PPDR applications based on the above technologies has been provided in Annexure

Intra-circle roaming

Intra-circle roaming (ICR) enables subscribers to maintain seamless connectivity when their primary service provider's network is either unavailable or has poor coverage within the same geographic area, known as a circle. This feature enhances the user experience by ensuring continuous service availability without manually switching to a different mobile number or provider. The key aspects of intra-circle roaming in India include

- **Network sharing agreements:** Telecom operators establish agreements to share their network infrastructure, allowing subscribers to automatically connect to a partner operator's network when their primary provider's signal is weak or unavailable within the same circle. This collaboration ensures uninterrupted connectivity for users.
- **Improved coverage and service quality:** ICR enables operators to offer enhanced coverage and service quality, particularly in rural and remote areas where new infrastructure development may be challenging and expensive. This approach helps bridge coverage gaps, providing more consistent service to customers.
- **Regulatory oversight:** The TRAI oversees the implementation and regulation of ICR agreements. TRAI ensures these agreements are fair and non-discriminatory, fostering healthy competition and benefiting consumers by promoting better service options.
- **Benefits to consumers:** ICR significantly improves the user experience by ensuring continuous service availability. Subscribers can make and receive calls, send texts, and use data services without worrying about coverage gaps within the same circle, leading to greater satisfaction and reliability.

Common alerting protocol

The common alerting protocol (CAP) is a domestically developed platform that empowers disaster management authorities to deliver targeted and automated multi-hazard alerts to citizens in near real-time and in multiple languages. By integrating various stakeholders, CAP helps bridge information gaps and employs a range of technologies—including SMS, cell broadcast, mobile apps, television, radio, social media, RSS feeds, and browser notifications—to ensure effective communication and last-mile reachability. The system is built on the ITU-X 1303 CAP standard and operates nationwide across India, providing crucial alerts and warnings in the event of a disaster.

Sachet

Sachet is a comprehensive dashboard that consolidates and publishes official disaster warnings from various authorized sources. Built on the CAP, it serves as an integrated alert system, ensuring timely and accurate dissemination of information for all types of disasters.

Standard operating procedure 2020 for telecommunications services for responding to disasters

The standard operating procedure encompasses various aspects, from mitigation to recovery to minimizing disaster-related losses:[39]

- **Coordination:** Facilitate collaboration among multiple agencies for disaster preparedness, response, and recovery efforts
- **Institutional Structure:** Establish a two-tier framework for disaster management within the telecom sector
- **Disaster Response Task Force (DRTF):** Recommend maintaining a DRTF for Telecom Service Providers (TSPs)
- **Resource Centres:** Ensure resource centres are operational during a disaster
- **Inter-Provider Agreements:** Develop memorandums of understanding (MoUs) between TSPs for coordinated service delivery in affected areas
- **Preparedness Review:** Regularly assess preparedness measures
- **Trigger Mechanisms:** Establish systems to activate response protocols
- **Flood and Earthquake Preparedness:** Implement minimum altitude requirements in flood-prone areas; ensure earthquake-resistant infrastructure and firefighting equipment
- **Network Redundancy:** Provide at least two distinct geographical paths for network and switching elements
- **Critical Components:** Identify critical network components for protection
- **Congestion Management:** Develop plans to manage network congestion
- **Network Over-Dimensioning:** Over-dimension core networks and Points of Interconnection (POIs)
- **Fibre Optics:** Install underground optical fibre in ducts to reduce vulnerability
- **Emergency Communication System:** Implement a single-number emergency communication and response system
- **Equipment Access:** Maintain storage facilities for quick access to equipment
- **Priority Services:** Provide immediate services to priority user groups
- **Situation Assessment:** Conduct on-the-spot assessments of the situation
- **Daily Status Reports:** Submit daily reports on the status of telecommunications facilities
- **Free Communication Services:** Offer free PCOs and broadcast messages
- **Service Continuity:** Ensure services are delivered for at least 15 days without commercial restrictions
- **DRTF Access:** Ensure access to the DRTF
- **Rapid Damage Assessment:** Maintain a Rapid Damage Assessment Team (RDAT)
- **Training and Drills:** Conduct regular training sessions and drills

4.1.3. Key initiatives taken in five states

Assam, Gujarat, Odisha, Tamil Nadu, and Uttarakhand are crucial in fostering a disaster-resilient telecommunications sector. By aligning their disaster management plans with national guidelines and streamlining right of way (RoW) permissions, these states facilitate the swift deployment and restoration of essential telecommunications infrastructure, especially after a disaster. Recognizing the critical importance of connectivity in resilience, Assam and Gujarat have implemented initiatives, such as a cell broadcast (CB)-based integrated public alert and warning system, to enhance emergency communication during crises. Additionally, Assam has developed the Disaster Reporting and Information Management System (DRIMS), a digital platform that enables real-time reporting of disaster-related damages to expedite response and recovery efforts.

In Tamil Nadu's coastal region, deep-sea fishermen rely on very high frequency (VHF) communication networks spanning 1,076 km (668.5 miles) to ensure reliable voice communication for small boats and voice and data connectivity for the fishing community. In Odisha, the early warning dissemination system (EWDS) integrates a range of communication technologies, including Digital Mobile Radio (DMR), Satellite-Based Mobile Data Voice Terminal (SBMDV), mass messaging systems, alert tower siren systems, and universal communication interfaces. This comprehensive system enables authorities to disseminate critical information and coordinate with disaster management officials, relief workers, and volunteers during emergencies, thereby minimizing the loss of lives. details state-specific initiatives aimed at enhancing the disaster resilience of telecommunications networks in Assam, Gujarat, Odisha, Tamil Nadu, and Uttarakhand.

Table 4.3: State-specific initiative to strengthen the disaster resilience of its telecommunications network

States	Action supporting telecommunications resilience initiative
Assam	1) The Revenue and Disaster Management Department, Assam State Disaster Management Authority (ASDMA) has: a) Prepared a fail-safe communication plan with all early warning agencies b) Established protocols and responsibilities for coordinating with central agencies c) Established coordination with mobile service providers 2) District emergency operating centres (EOCs) are equipped with satellite phones/VHF/HF as a backup to the landline. It ensures all communication equipment, especially the VSAT and satellite phones, are in good working condition 24x7 on all days through regular testing. It also has binding agreements with telecom service provider stores to re-damaged facilities and set up temporary facilities on an emergency basis. 3) The Department of Information and Public Relations and other relevant agencies are responsible for: a) Providing emergency communication to communities b) Coordinating the temporary communication requirement 4) In disaster events such as thunderstorms and lightning, the Information and Public Relations agency provides SMS by various telecom service operators to all active mobile connections. It also broadcasts alerts such as running flashes on the televisions/SMS run by local cable operators.
Gujarat	1) The District Emergency Operations Centre, with support from the DM, undertakes a) A fail-safe communication plan with all early warning agencies b) All communication equipment, especially satellite phones, are in good working condition 24x7 on all days through regular testing c) Plans for communication, including telephone and ham radio, are prepared for smooth coordination with the field-level IRTs d) The establishment of protocols and responsibilities for coordination with central agencies and various providers e) The preparation, updating and maintenance of a district-wise list of HAM operators who could be contacted and deployed at the site of emergency f) Binding agreements with telecom service providers to restore damaged facilities and set up temporary facilities on an emergency basis

States	Action supporting telecommunication resilience initiative
Odisha	1) The District Disaster Management Authority (DDMA) ensures communication systems are in order and disaster management drills are carried out periodically. 2) ST & SC Development, Minorities and Backward Classes Welfare Department prepares guidelines/circulars and manuals on the chain of command and communication regarding disaster prevention and preparedness actions. 3) Standard operating procedure to provide early warning through every mode of communication is to be utilized to make the early warnings. Radio, television, newspapers, sirens, public address systems and even beating the drums should be utilized to warn the public. 4) The block development officers (BDOs) keep all resources ready, like polythene, tarpaulins, boats, generators, diesel/petrol/kerosene, and transportation and communication aids available and other necessary equipment listed in the gram panchayats (GPs). 5) Disaster Assistance Monitoring Payment System (DAMPS) provides an efficient and transparent disbursement of ex-gratia payments to families of deceased persons.
Tamil Nadu	1) The Department of Science and Technology issues alerts/warnings through mass SMS by establishing liaisons with telecom service providers. It also ensures the safety and serviceability of critical communication towers through respective service providers. To facilitate this, it has established alternate communication links like HF, VHF, HAM, satellite phones, etc. 2) The Municipal Commissioner and the Telecom Service Provider undertake the following: a) Issues alerts/ warnings through SMS by establishing a liaison with the service providers b) Ensures the safety and serviceability of critical communication towers through respective service providers c) Ensures the establishment of alternate communication links like HF, VHF, HAM, satellite phones, etc. 3) The district-level concerned departments have binding agreements with telecom service providers to restore damaged facilities and set up temporary facilities on an emergency basis. It also ensures inter-operability among different telecom service providers.
Uttarakhand	1) To ensure steady communication in the aftermath of any disaster, Mini M satellite phones have been provided at the state emergency operating centre (SEOC) and 10 district emergency operating centres (DEOCs) 2) DM/SEOC establishes communication links by activating alternate communication equipment, i.e., satellite phone, HF/ VHF set, VSAT, etc., in state/district EOCs and control rooms. 3) State Disaster Management Authority (SDMA) facilitates the development of mobile emergency communication units in affected areas for establishing communication links. 4) The Secretary, Transport, along with the Secretary, Civil Aviation and the Secretary, Disaster Management, assess the conditions of road, rail and air communication links for quick mobilization of emergency teams and resources to affected areas and take follow-up actions.

Source: Stakeholder consultation[40]

It is evident that these states are not only providing coordinated and practical support in building a more resilient and disaster-prepared telecommunication sector across India but also adopting a localized and structured approach to further strengthen it.

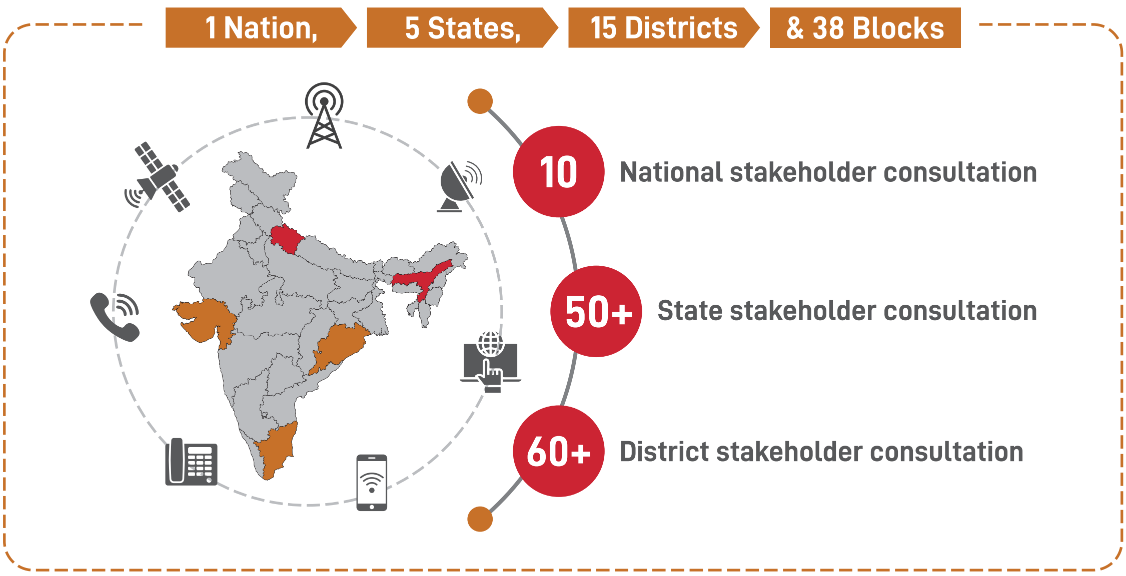
Additionally, the state of Gujarat has adopted Power Line Carrier (PLC) communications for electrical utility automation, owing to its cost-effectiveness and rapid implementation. Distribution companies are also leveraging PLC communications for various smart grid applications, including Advanced Metering Infrastructure (AMI) and Supervisory Control and Data

Acquisition (SCADA). In Gujarat, 4 PLC protocols have been tested under smart grid pilot projects to test the reliability of data transfer. The result indicates a success rate of approximately 94% for data transferred every six hours and about 98% for data transferred every 24 hours.[41]

4.2. Ground-level examination of key issues

The project team consulted different stakeholders at both national and sub-national levels to examine the key issues on the ground. The key objectives of widespread stakeholder consultation across different geographies of the country are as follows:

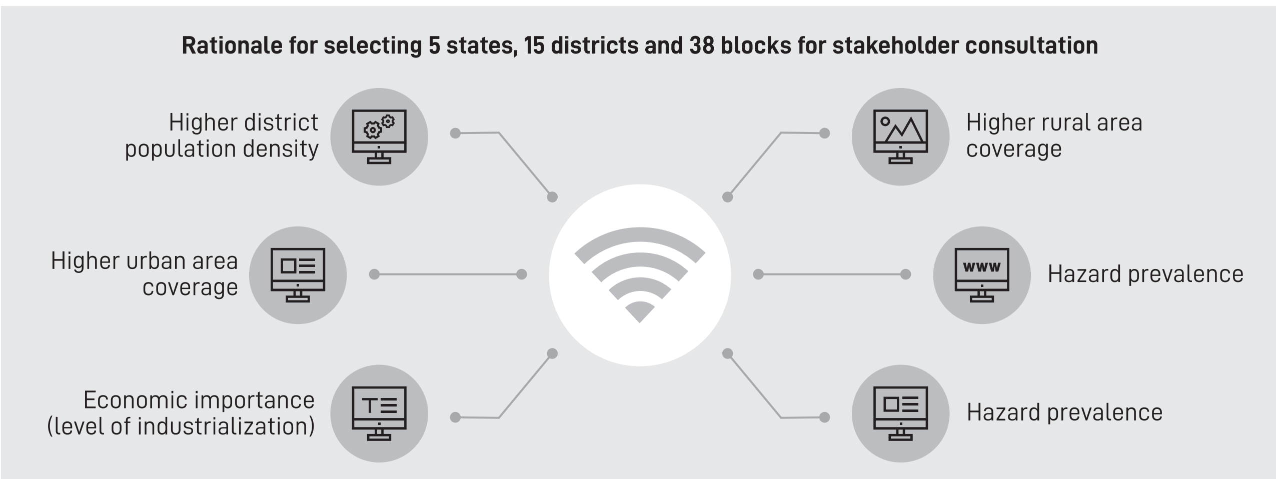
- Capture perceptions of external stakeholders at the national, state and district levels involved in this study
- Collect primary and secondary data from the field



120 meetings were held with more than 600 stakeholders nationwide to gather insights into their risk perceptions and understand local practices for mitigating disaster risk. A detailed breakdown of the consulted stakeholders is shown above.

4.2.1. Selection of three most vulnerable districts across five states for stakeholder consultations

To capture a comprehensive ground insight, the three most vulnerable districts across five selected states, which are a mix of mountainous, plain and coastal regions and face different types of natural hazards, were shortlisted considering the following criteria:



A list of districts where extensive stakeholder consultation was conducted through focused group discussions and key informant interviews is presented below:

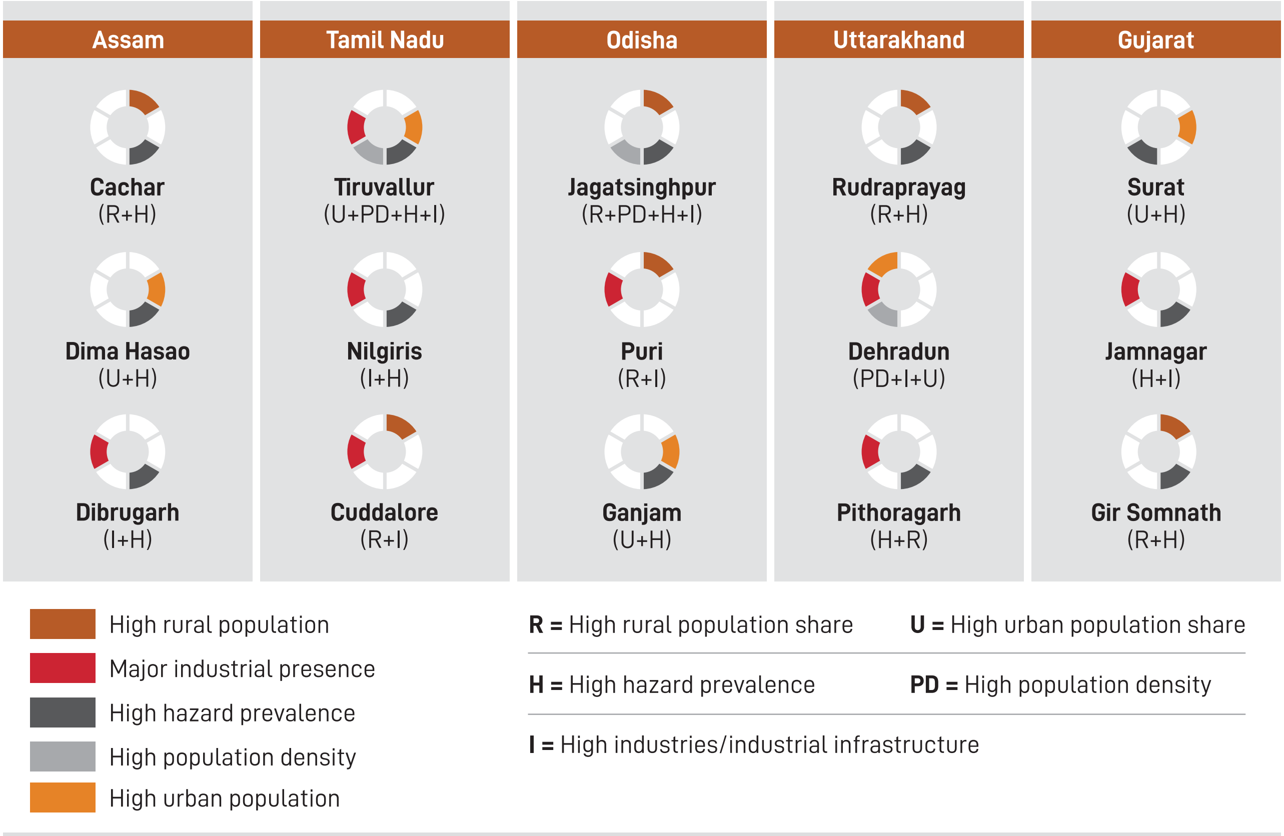


Figure 4.1 : List of districts for stakeholder consultations

A list of blocks where community consultations with different stakeholder groups were conducted is presented in Figure 4.2.

Odisha	**Ganjam -** Chattrapur, Ganjam & Rangeilunda block, **Jagatsinghpur-** Kujanga, Tirtol & Erasama block, **Puri-** Krushnaprasad, Astarang & Gop block
Uttarakhand	**Dehradun-** Chakrata and Kalsi block, **Rudraprayag-** Agastyamuni block, **Pithoragarh-** Munsiyari & Dharchula block
Gujarat	**Somnath-** Veraval, Sutra Pada & Una block, **Surat-** Surat Urban block, **Jamnagara-**Lalpur & Jamnagar rural block
Assam	**Dibrugarh-** Panitola, Barbaruah & Lahowal block, **Dima Hasao-** Haralgajao & Mahur block, **Cachar-** Borkhola, Kalain & Katigorah block
Tamil Nadu	**Tiruvallur-** Minjur (Village Panchayat), Poonamallee (Municipality) and Avadi Corporation, **Cuddlore-** Cuddalore, Parangipettai & Kurinjipadi block, **Nilgiris-** Coonoor, Kundah & Guldalur block

Figure 4.2 : List of blocks for community consultation

4.2.2. Sample questionnaire for assessing on-ground disaster risk perception and resilience practices

The sample questionnaire developed to capture the stakeholders' disaster risk perception and resilience practices adopted in various geographical regions is presented in Table 4.4.

Table 4.4 : Sample questionnaire for assessing on-ground disaster risk perception and stakeholder resilience

Dimensions	Questions
Policy, Institutions and Process	• What policies and processes are in place to implement, monitor and adapt to the regulatory framework for ensuring telecom resilience? • Is there any policy/guideline to define priority restoration of the telecommunications assets to maintain its seamless connectivity? • What policies and guidelines are in place for community engagement and participation in informed decision-making? • What are the policies/guidelines for adopting the global/national/regional best practices on a periodic basis? • Are there any guidelines/policies that define the ownership on roles and responsibilities of various stakeholders involved at block, district, state and national levels to ensure the resilience of the telecommunications system for seamless connectivity to the last mile? • Are there any guidelines/policies that define a timeframe for the restoration of the network based on the critically of the nodes/hub sites? • Are there any policies/guidelines in place to maintain event-wise records of telecommunications asset damage and loss due to various disaster events? • What policies/guidelines are in place to maintain the record of the revenue/ monetary loss due to network/infrastructure damage from disasters? • Are there any guidelines in place to record the non-operational time and corresponding business/operational losses due to hazard impacts? • Is there any guideline/policy to record the restoration cost of telecommunications assets/telecommunications services? • Is there any roadmap/guidance document available to handle future shocks based on the anticipated severity of hazards? • Are there any guidelines/standard operation procedures to provision power supply/power channels or backup power to ensure adequate supply for the functioning of critical nodes/minimum telecommunications network at both vulnerable and critical regions? • Is there any process in place to ensure the availability of a dedicated fuel supply and mechanism for the supply? • Is there any process in place to document and share all global/national/regional/ local best practices to strengthen the resilience of the telecommunications system? • Is any process defined for information exchange among the stakeholders within/across the telecommunications sector?

Dimensions	Questions
Technical Planning and Design	• Is there any comprehensive and integrated geodatabase available for telecommunications assets at the national/state level to assess and monitor the disaster risk at the central/state level? • Is there any state or region-specific infrastructure standard available for the telecommunications system to ensure uninterrupted functioning even during disasters/catastrophic conditions? • What are the various redundancy measures in place to increase the resilience of the telecommunications infrastructure system? • What measures are in place to prioritize asset restoration/strengthening based on its criticality? • Is there any plan in place to upgrade the technical standards against both existing and emerging shocks/stress/hazard events periodically? • Does the telecommunications sector/telecommunications body maintain historical records on connectivity loss, equipment loss, recovery time, restoration time, revenue loss, etc., due to disasters? • Is there any plan in place to forecast the energy/power requirement to keep the telecommunications system running 24/7? • Are there guidelines in place for ensuring seamless connectivity without compromising on security standards of telecommunications assets and shared sustainability goals?
Operation and Maintenance	• What asset management practices are in place to optimize the telecommunications asset performance throughout its lifecycle? • What operational measures are in place to tackle the known hazard risks (e.g., flood, cyclone, earthquake, landslide) and their impact on telecommunications assets? • Does the department conduct any internal assessment to understand the potential impact of future hazards on the operation and functionality of the telecommunications system?
Financial Arrangements and Incentives	• What financial arrangements (special provisions) are in place to share the risk of the telecommunications infrastructure system? • What financial arrangements are available with the departments to ensure adequate financing for technological upgradation, raising existing infrastructure standards, asset replacement and emergency restoration of telecommunications infrastructure and services? • Is there any State-level or National-level dedicated financial corpus available for research and development to strengthen the resilience of the telecommunications infrastructure system? • Is there any contingency support in place to support the financial gap for quick recovery and restoration of services?
Expertise	• Is there a dedicated pool of manpower within the organization who can periodically ensure an effective response to any hazard events? • Is there any dedicated platform available for information sharing/peer-to-peer learning among the different stakeholder groups?

4.2.3. Common challenges across selected states

This section summarizes the common challenges[42] encountered by five states at various stages of disaster management. Addressing these issues is crucial for enhancing the resilience of the telecommunications infrastructure nationwide. Successfully overcoming these challenges can significantly improve liveability and promote socio-economic development across the states.

Operations & maintenance

- *Limited fuel, power & logistic availability*
- *Insufficient CoWs & alternate communications technologies available at last mile*
- *Network congestion*

Financial arrangement

- *Insufficient funding arrangement for establishing emergency communication*
- *Insufficient risk sharing instruments*
- *Lack of business model for remote consumer connectivity*

Technical planning & design

- *Infrastructure design unable to withstand increasing disaster impacts*
- *Limited historical damage & loss information*
- *Insufficient telecommunications network & services availability*
- *Limited infrastructure redundancy*
- *Interoperability issues*

Policy Institutions and Processes

- *Lack of priority network restoration guidelines*
- *Lack of single window permission system*
- *Right of Way (RoW) policy implementation issues*

Expertise

- *Insufficient manpower at institutions*
- *Consumer awareness gap*

4.2.4. State-specific challenges and good practices

A few of the state-specific challenges and good practices[43] collated during the field consultations are tabulated below:

States	Challenges	Good practices
Uttarakhand	• Damage of telecommunications assets due to forest fire • More than three months of service interruption due to heavy snowfall in the high-altitude region	• Deployment of drone for network restoration and damage assessment • Buffer stock of diesel at strategic location • Leverage radio Kedar for emergency communication purposes
Assam	• Inundation of DG sets and other support infrastructure • River erosion impacts the foundation of the tower	• VHF system available across all revenue circle offices for emergency communication • Formation of human chain to supply fuel to critical site network • Allocation of three percent of the state budget for financing disaster-resilient infrastructure • Disaster communication through village heads (Gaon burha), government schoolteachers and local youth leaders
Gujarat	• Impacts on RTT tower due to building damages across coastal regions • Survivability issue of antenna in high wind	• Common duct for faster rollout of broadband infrastructure • Provision of power supply to rural telecommunications assets through dedicated agri feeder
Odisha	• Lack of well-defined guidelines for installing telecommunications towers at disaster shelters • Lack of dedicated telecommunications network at critical industrial locations	• Provision of three different power supply sources for the DC • Response plan to restore power within 48 hours
Tamil Nadu	• Frequent damage to submarine cables due to anchoring of the fishing boats • Lack of robust framework for faster repairing of submarine cables	• Cell on Wheels (CoWs) are equipped with mobile charging points and lights • SMS alert system for pre-programmed power shutdown

4.2.5. Rapid visual survey of vulnerable assets across five states

After identifying the three most vulnerable districts across five selected states, the project team visited the selected impacted telecommunications tower sites to assess the degree of damage in relation to the intensity and spatial reach of recent hazards in the region. Figure 4.3 and the table in Annexure 5 present the details of 15 highly vulnerable telecommunications towers due to recent disaster events across five states. This will help devise the recommendations for changes required in the technical design, operation, and maintenance of the telecommunications towers located across such regions.

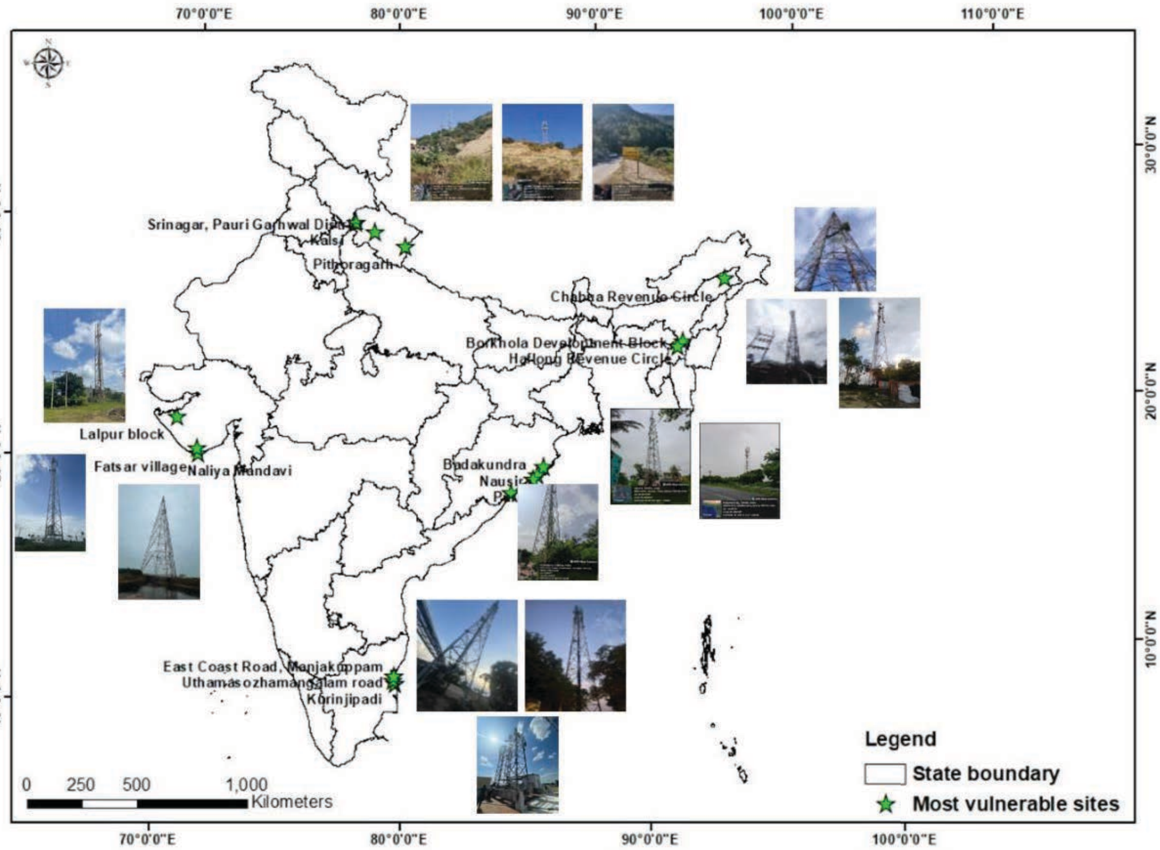


Figure 4.3: Most vulnerable site locations in selected five states

4.2.6. Weakest element across three miles of the telecommunications network

Based on the extensive consultation with different stakeholders across geographies and all three miles of the telecommunications network, it has been established that different infrastructure elements exhibit different degrees of vulnerability to hazards. The vulnerability profile changes across geographies, which may require comprehensive monitoring and assessment of the impact on the overall network failure.

Table 4.4 presents the element across different miles of the network.

Table 4.5: Weakest elements of telecommunications infrastructure system

Hazards	First mile	Middle mile	Last mile
Coastal erosion	Sub-marine cables	Optical fibre	Telecommunications tower and optical fibre
Flood	Cable landing station	Optical fibre, Data centre	Generator & power back up and optical fibre
Landslide	-	Optical fibre	Telecommunications tower
Cyclone/windstorm	Cable landing station	Earth-station, Data centre	Antenna and telecommunications towers
Earthquake	Cable landing station	Optical fibre, Data centre	DG sets, Building & telecommunication tower

5.

Multi-hazard risk mapping of telecommunications assets

5.1. Background

India's diverse topography, encompassing hills, plains and coastal regions, significantly influences the design and operation of telecommunications infrastructure. This infrastructure is subject to numerous hazards across the country's states and union territories. Out of the 36 states and union territories, 27 are considered hazard prone. Approximately 58.6 percent of the landmass is at risk of earthquakes, 12 percent is vulnerable to flooding and 15 percent is prone to landslides. Additionally, 5,700 km (3541.8 miles) of India's coastline are threatened by tsunamis and cyclones. This study focuses on major hazards, including landslides, floods, cyclones, storm surges, lightning, forest fires, flash floods and earthquakes.

It is essential to identify and map all natural hazards in the region that significantly affect the telecommunications infrastructure system. While an all-hazard approach, which includes natural, human-induced, and environmental hazards, is typically the most effective method for assessing risks to critical infrastructure, this assignment will concentrate solely on natural hazards and their potential impacts on telecommunications infrastructure. Table 5.1 offers a comprehensive list of the natural hazards mapped across the five selected states under this assignment.

Table 5.1: List of natural hazards mapped for the selected five states

Sl. No.	Name of the state	Types of natural hazards		
		Geo-physical	Hydrological	Meteorological
1	Assam	• Earthquake • Landslide	• Flood	• Cyclonic wind • Extreme wind
2	Gujarat	• Earthquake • Landslide	• Flood	• Cyclonic wind • Storm surge • Extreme wind
3	Odisha	• Earthquake • Landslide	• Flood	• Cyclonic wind • Extreme wind • Storm surge
4	Tamil Nadu	• Earthquake • Landslide	• Flood	• Cyclonic wind • Storm surge
5	Uttarakhand	• Earthquake • Landslide	• Flood • Flash Flood	• Forest fire • Cyclonic wind

Geographic information systems (GIS) play a crucial role in mapping the multi-hazard risks that infrastructure systems face at various scales. They help assess the exposure and vulnerability of these systems to multiple hazards. The frequency, severity, duration, and spatial extent of hazards determine the degree of exposure and vulnerability of any infrastructure system. Figure 5.1 illustrates a comprehensive approach for multi-hazard risk mapping of telecommunications infrastructure systems.

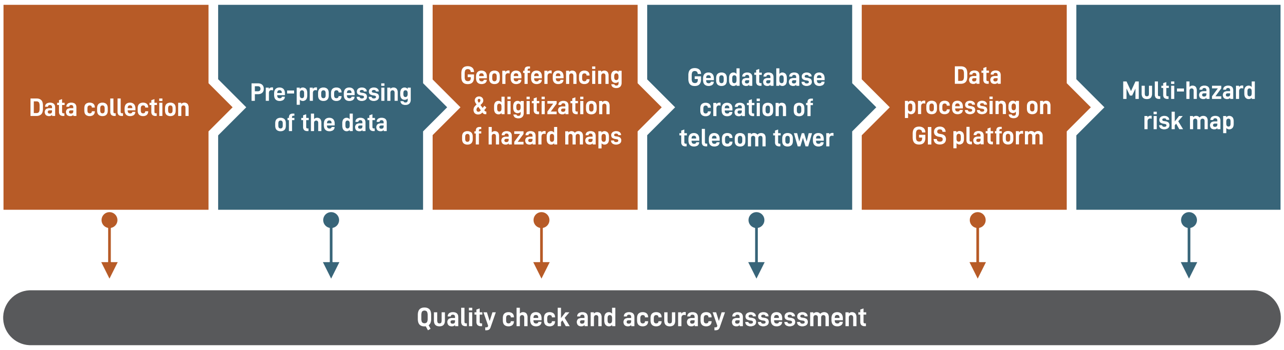


Figure 5.1: Methodology for multi-hazard risk mapping of telecommunications towers

The datasets used in this study were sourced from various organizations, including the Indian Meteorological Department (IMD), State Disaster Management Authority (SDMA), Building Materials and Technology Promotion Council (BMTPC), Survey of India (SoI), Geological Survey of India (GSI) and DoT. Extensive pre-processing was conducted to ensure consistency and accuracy and create seamless datasets by removing any inconsistencies and errors. Georeferencing was performed on the different data layers to establish spatial correlations with ground reference points, and the datasets were digitized using a GIS platform. Data on telecommunications assets, specifically the locations of telecommunications towers provided by the DoT, were integrated into the geospatial platform to create a comprehensive geodatabase. This geodatabase facilitates geospatial analytics for developing multi-hazard risk maps. Additionally, spatial queries were executed to identify telecommunications towers located within hazard-prone zones across selected states and throughout India. Rigorous quality checks and accuracy assessments were conducted at various stages to ensure the reliability of the maps. This mapping encompasses eight key hazards significantly impacting telecommunications infrastructure across various miles. The key insights gained from this mapping and the data sources are presented in the section below.

Table 5.2: Datasets required for mapping and their corresponding sources

S. No.	Source	Dataset
1	Building Materials and Technology Promotion Council (BMTPC)	Earthquake and Cyclonic Wind
2	Indian Meteorological Department (IMD)	Flood, Storm surge, Cyclonic Wind
3	State Disaster Management Authority (SDMA)	Cyclonic Wind, Landslide, Flood
4	IIT-Delhi Research Publication 'Sharma, N., Saharia, M., & Ramana, G. V. (2024). High-resolution landslide susceptibility mapping using ensemble machine learning and geospatial big data'. Catena, 235, 107653, GSI	Landslide
5	Forest Survey of India	Forest Fire locations
6	DDMA, Jamnagar	OFC network
7	APDCL, Noiboicha	Power distribution network
8	Department of Telecommunications (DoT), GoI	Telecommunications tower
9	Survey of India	Administrative boundaries

5.2. Hazard risk mapping at national scale

Data on 0.77 million telecommunications towers collected from the DoT, Government of India, have been mapped using a GIS platform. This mapping allows for assessing the hazard risk categories for these towers nationwide.

Landslide

Approximately 15 percent of India's landmass is prone to landslides, affecting areas such as the Himalayas, the northeastern region, the Western Ghats, the Nilgiris, the Vindhyas and the Eastern Ghats. About 4.75 percent of the land is highly susceptible to landslides. States such as Himachal Pradesh, Uttarakhand, Maharashtra, Jammu and Kashmir, Kerala, Mizoram, Karnataka, Nagaland, Sikkim, Arunachal Pradesh, Meghalaya, Manipur, Tamil Nadu and Assam experience significant impacts from landslides.   illustrates the mapping of telecommunications towers exposed to various landslide hazard categories, and the accompanying table presents the percentage distribution of these towers located in regions with moderate to high landslide susceptibility across the country.

Hazard category	Towers (%)	No. of towers
Very high	2.23	17,369
High	1.96	15,292
Moderate	1.85	14,425

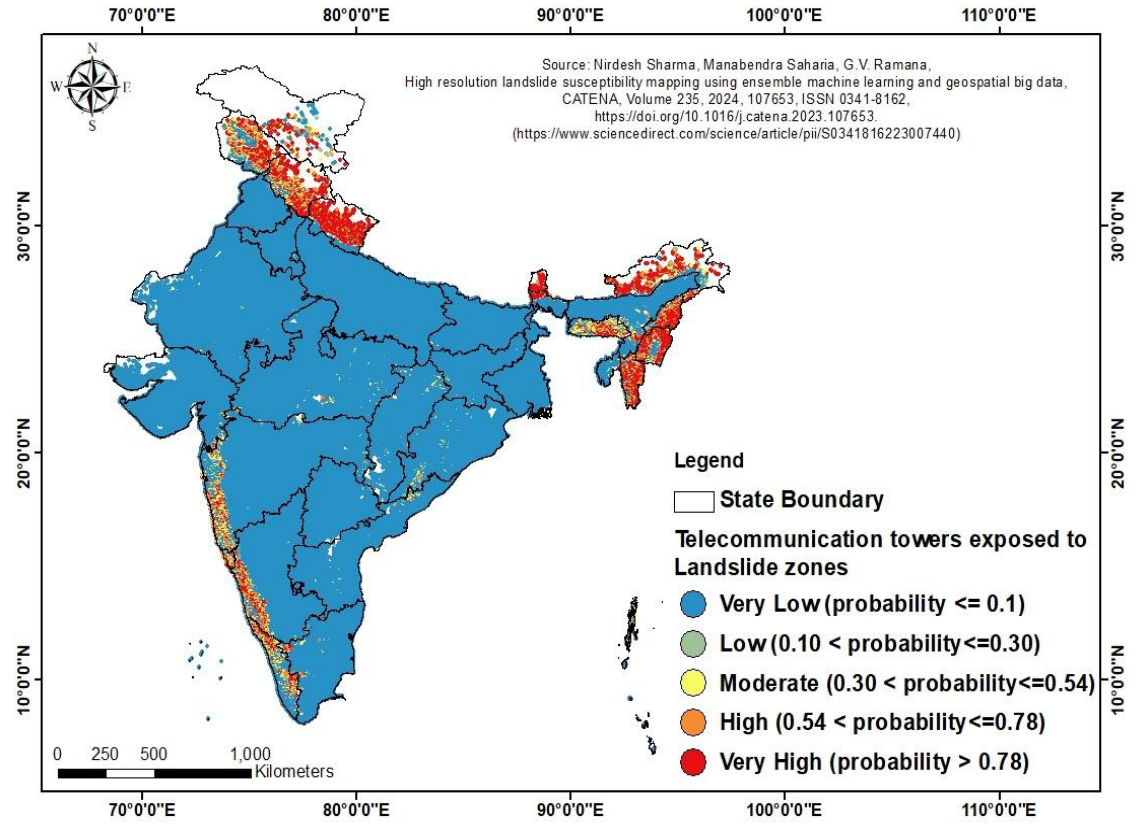


Figure 5.2: Landslide exposure mapping of telecommunications towers in India

Earthquake

Earthquake is another geophysical hazard that can significantly impact the telecommunications assets. In India, there are four earthquake zones (II, III, IV, V), each indicating an increasing risk of damage. Seismic zone V encompasses Gujarat, Uttarakhand, Himanchal Pradesh, Jammu and Kashmir, and northeastern states, making these areas highly vulnerable to earthquake hazards. Figure 5.3 illustrates the mapping of telecommunications towers exposed to various seismic zones and the accompanying table presents the percentage distribution of these towers located in various seismic across the country. Most of the telecommunications assets (approximately 40 percent) fall under zone III, while 20.6 percent are located in zone IV and 6.4 percent of the total assets comes under zone V, respectively. The telecommunications towers in these regions are at much higher risk from earthquakes.

Hazard category	Towers (%)	No. of towers
Zone V	6.4	49,736
Zone IV	20.6	160,280
Zone III	40	315,679

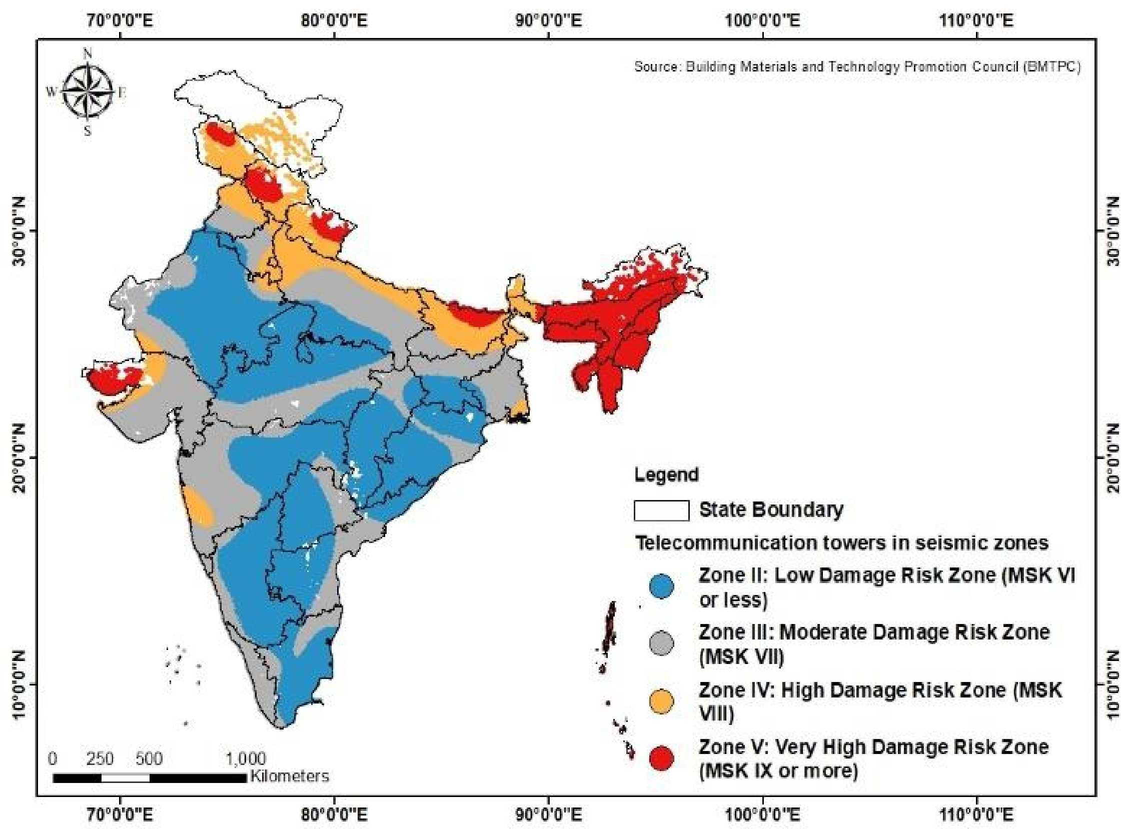


Figure 5.3: Earthquake exposure mapping of telecommunications towers in India

Storm surge

Coastal states in India are mostly affected by storm surges, which result from an unusual rise in the sea level caused by tropical cyclones or storms.[44] The IMD has mapped the districts in these coastal states that are vulnerable to storm surges, with heights ranging from 2.5 to 13.7 m. Figure 5.4 illustrates the mapping of telecommunications towers exposed to different storm surge height categories, and the accompanying table presents the percentage distribution of these towers located in regions (7 km/ 4.34 miles from the coast) susceptible to different storm surge heights across the country. The eastern coast is exposed to a much higher range of storm surges, exposing the telecommunications towers to higher risk in these areas. West Bengal, Andhra Pradesh and Tamil Nadu are especially susceptible to storm surge greater than 6 m

Storm surge (m)	Towers (%)	No. of towers
11.1-13.7	0.92	7,221
8.1-11.0	0.06	537
6.1-8.0	0.12	908

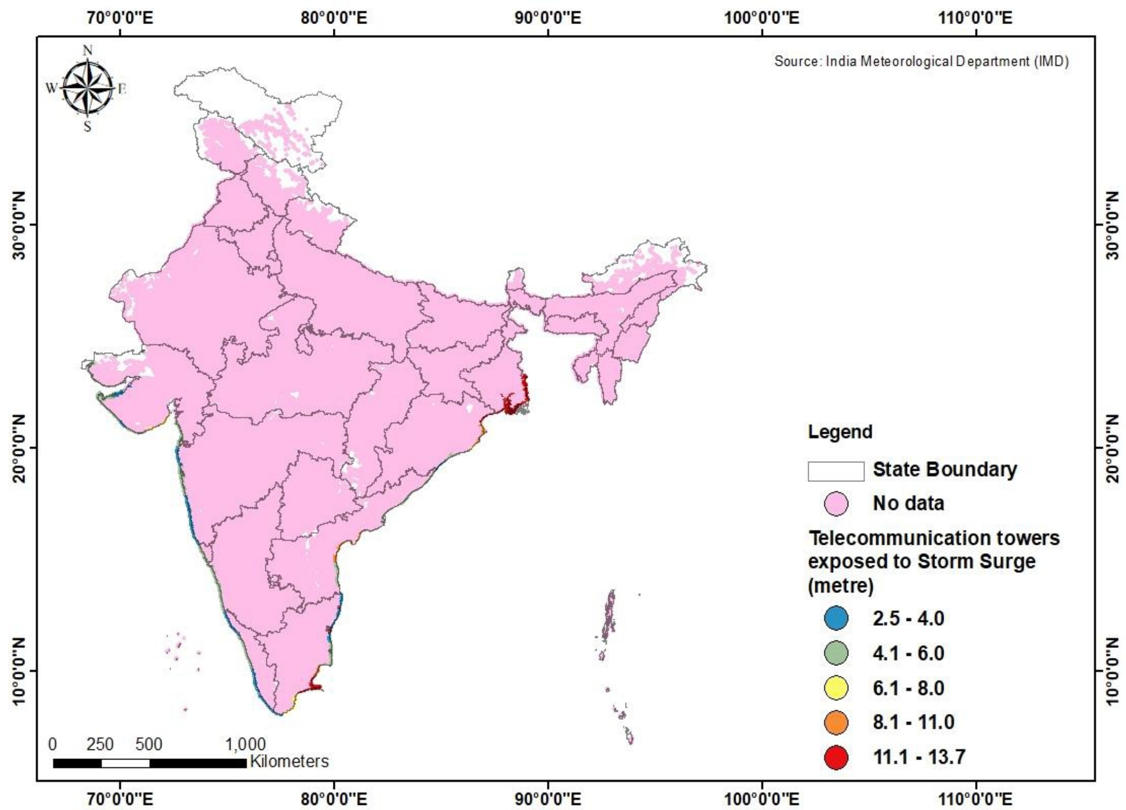


Figure 5.4: Storm surge exposure mapping of telecommunications towers in India

Cyclonic wind

Cyclones are hydrometeorological hazards that cause significant damages to life and infrastructure. There are 74 districts with coastal boundaries and 26 districts located further from the coast, making a total of 100 districts prone to cyclones.[45] BMTPC has categorized different regions of India into various damage risk zones as per the basic wind speed (Vb).[46] The telecommunications towers are mapped in these cyclonic wind risk zones to identify the towers at risk and are shown in Figure 5.5. Currently, 0.2 million (26 percent) telecommunications towers are exposed to the very high damage risk zone. The percentage distribution of telecommunications towers exposed to various cyclonic wind zones is shown in tabulated below.

Hazard category	Towers (%)	No. of towers
Very high (A)	0.82	6,420
Very high (B)	26	198,940
High	30	232,104

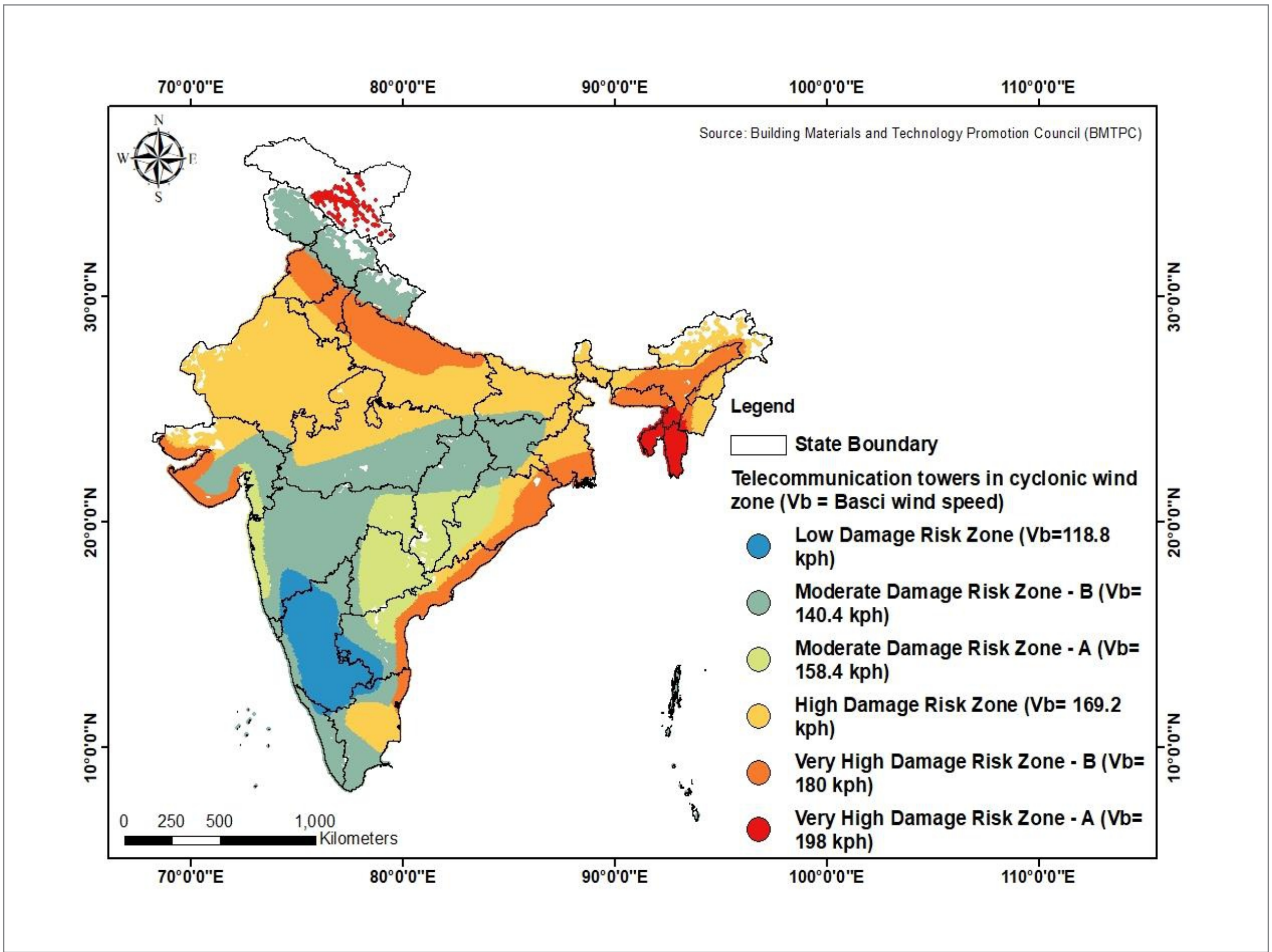


Figure 5.5: Cyclone exposure mapping of telecommunications towers in India

Flood

India is highly susceptible to floods, with around 40 million hectares of land at risk every year, resulting in significant damage to humans, infrastructure and critical facilities.[47] The IMD provides necessary updates and alerts to reduce the damage due to floods; however, flooding remains a major hazard, with numerous events reported every year. Floods pose a significant threat to telecommunications assets and disrupt emergency communication both during and after disasters. The IMD has categorized different districts in terms of the number of flood events. The telecommunications towers are mapped in these districts, and, accordingly, the towers at risk are estimated. Figure 5.6 illustrates the mapping of telecommunications towers exposed to flood hazard categories. The accompanying table presents the percentage distribution of these towers located in regions with moderate to very high floods across the country.

Hazard category	Towers (%)	No. of towers
Very high	6	44,461
High	11	86,956
Moderate	26	201,390

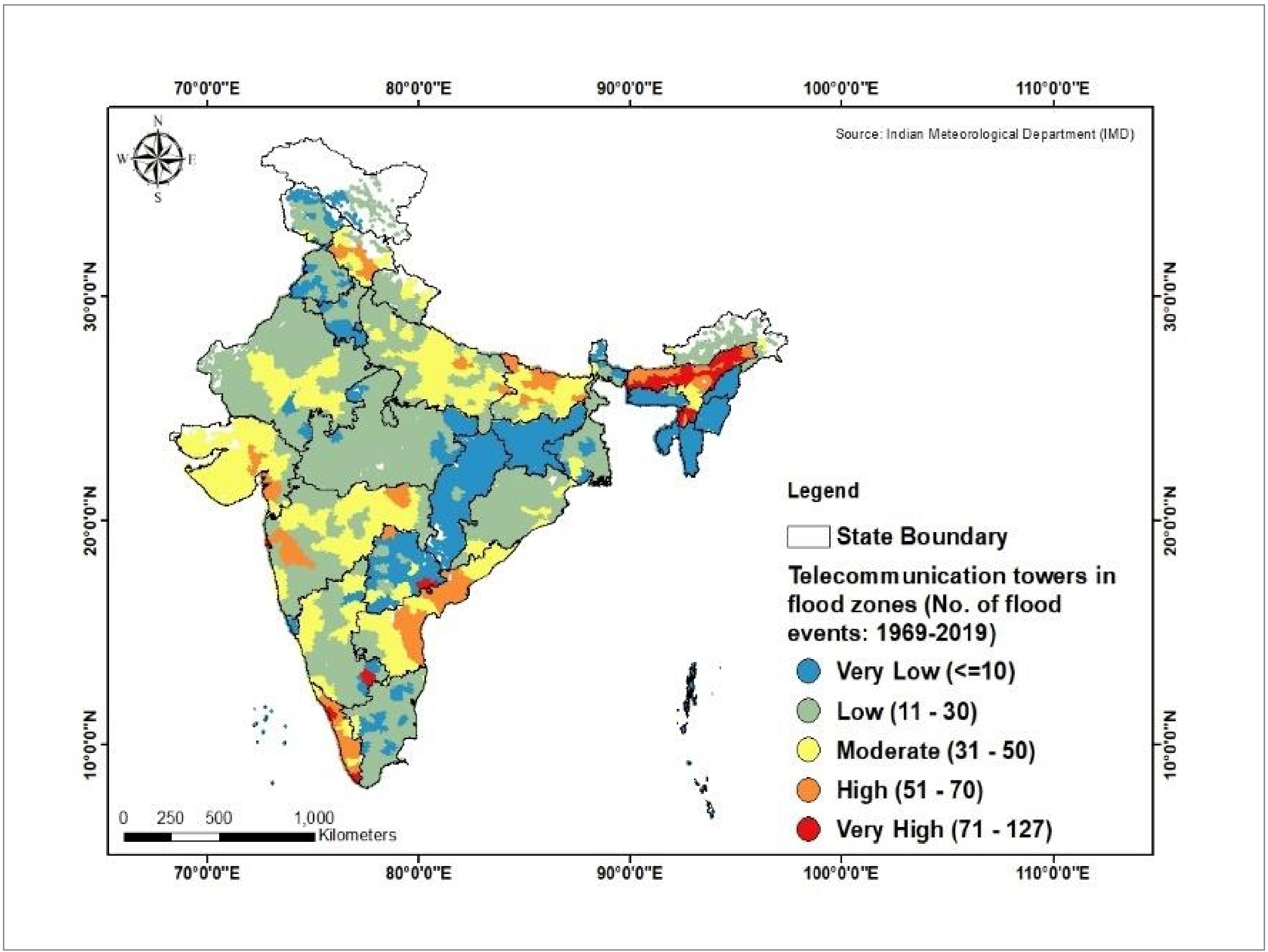


Figure 5.6: Flood exposure mapping of telecommunication towers in India

Lightning

Recent attention has focused on the hazards posed by lightning, as the damage to life and infrastructure continues to increase every year. Global warming is a significant factor contributing to the increased intensity and frequency of lightning strikes.[48] Climate Resilient Observing Systems Promotion Council (CROPC) has mapped the number of lightning strikes across the country. Figure 5.7 illustrates the mapping of telecommunications towers exposed to different lightning strikes, and the accompanying table presents the percentage distribution of these towers located in regions having several lightning strikes greater than 0.2 million. Approximately 0.23 million telecommunications towers are situated in the states with more than 0.4 million lightning strikes.

No. of lightning strikes	Towers (%)	No. of towers
>400,000	30	234,679
200,000–400,000	45	350,534

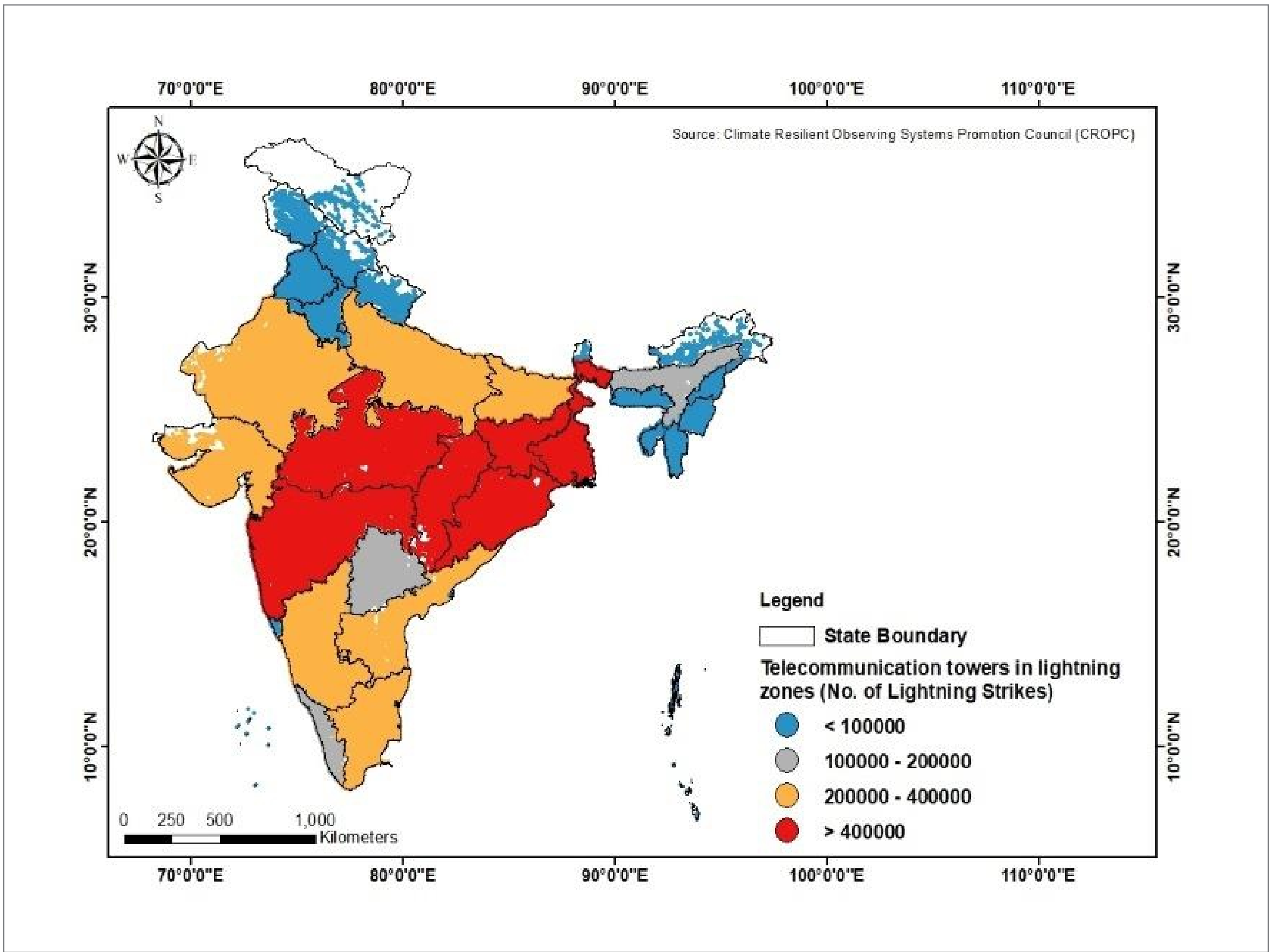


Figure 5.7: Lightning exposure mapping of telecommunications towers in India

5.3. Multi-hazard risk mapping for selected five states

Uttarakhand

Uttarakhand, a mountainous state in northern India, is characterized by significant elevation variations in its topography and is vulnerable to a wide range of hazards, including earthquakes, landslides, flash floods, forest fires, floods and cyclonic winds. The state falls within seismic zones IV and V, which poses a considerable threat to telecommunications infrastructure. Certain districts such as Udham Singh Nagar, Haridwar, Nainital, Champawat and Pauri Garhwal are particularly susceptible to strong cyclonic winds. Tehri Garhwal, Pauri Garhwal and Pithoragarh have the highest number of telecommunications towers at risk from landslides. Almora and Pauri Garhwal also have a significant number of towers exposed to flash flood hazards. Additionally, Dehradun and Pithoragarh receive more than 35 days of heavy rainfall annually. Moreover, nearly 1 percent of the telecommunications towers are located in areas highly sensitive to forest fires.

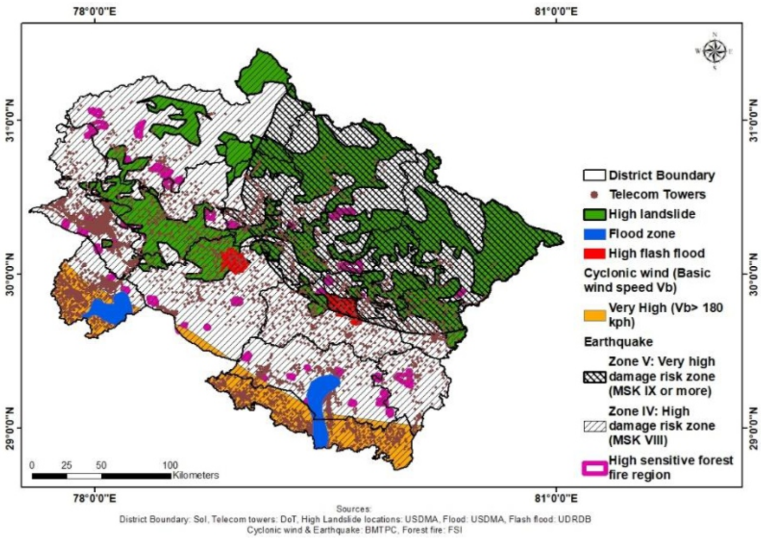


Figure 5.8: Multi-hazard exposure mapping of telecommunications towers: Uttarakhand

Figure 5.8 depicts the mapping of 9,756 telecommunications towers exposed to these hazards, while Table 5.3 shows the percentage distribution of these towers situated in areas across the state with moderate to high hazard susceptibility.

Table 5.3: Number of towers exposed to multi-hazards in Uttarakhand

Hazard	Towers (%)	No. of towers
Flood	5	485
Very high cyclonic wind	25	2,440
Earthquake zones IV and V	100	9,756
High landslide	10	981
High flash flood	<1	66
High forest fire	<1	38

Assam

Assam, located in the northeastern region of India, is highly prone to floods, cyclonic winds, landslides and earthquakes. The entire region of Assam lies in zone V for earthquakes, posing a significant threat to telecommunications assets. Several districts, such as Kamrup, Nagaon, Cachar and Dibrugarh are particularly susceptible to very high cyclonic wind zones. Flooding is common in many districts of Assam, with Nagaon, Barpeta, Lakhimpur and Tinsukia districts being especially prone to floods, putting many telecommunications towers at risk. Additionally, the Kamrup Metro and Dima Hasao districts are particularly susceptible to severe landslides, with the maximum number of telecommunications towers in those areas exposed to landslides.

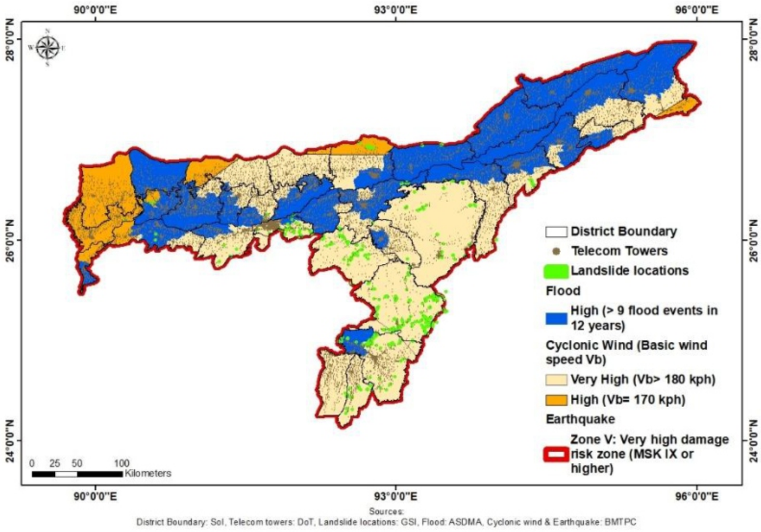


Figure 5.9: Multi-hazard exposure mapping of telecommunications towers: Assam

Figure 5.9 depicts the mapping of 18,388 telecommunications towers that are exposed to these hazards, while Table 5.4 shows the percentage distribution of these towers situated in areas across the state with moderate to high hazard susceptibility.

Table 5.4: Number of towers exposed to multi-hazards in Assam

Hazard	Towers (%)	No. of towers
High flood	43	7,865
Very high cyclonic wind	83	15,352
Earthquake zone V	100	18,388
High landslide	5	1,032

Tamil Nadu

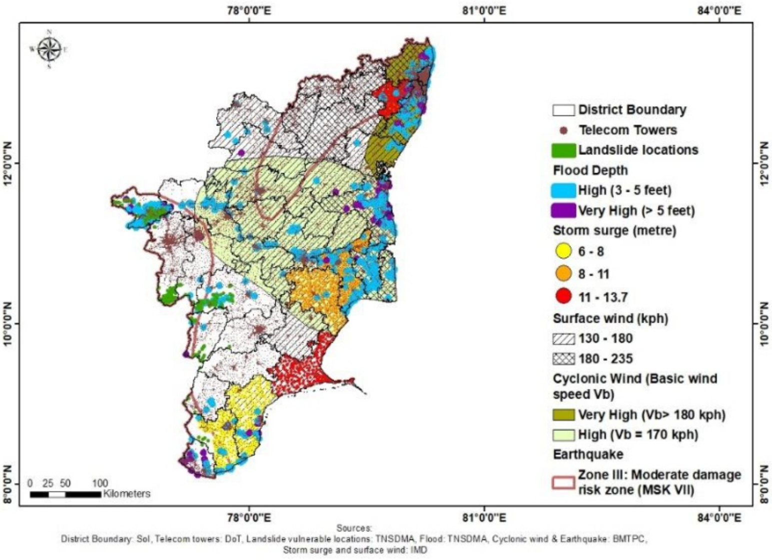


Figure 5.10: Multi-hazard exposure mapping of telecommunications towers: Tamil Nadu

Tamil Nadu is a coastal state in southern India. A major portion of it lies in seismic zone III, which poses a moderate risk to telecommunications assets. In recent years, flooding has become a frequent occurrence in the state. Flood-prone locations are identified by the Tamil Nadu SDMA, and a buffer of 2 km/1.24 miles is drawn to identify which telecommunications towers are at risk. Chennai, Chengalpattu and Kanchipuram districts have the maximum number of towers exposed to very high flood levels. Tamil Nadu is also severely affected by cyclonic winds, with large areas of the state categorized as being in very high- and high-risk categories. The Chennai, Chengalpattu and Tiruvallur districts are susceptible to very high cyclonic wind zones, threatening maximum telecommunications towers. Kanchipuram, Thanjavur and Tirunelveli are the top three districts susceptible to storm surge greater than 6 m. The Nilgiris and Dindigul districts are susceptible to high landslides and have the maximum number of telecommunications towers exposed to landslides.

Figure 5.10 depicts the mapping of 48,416 telecommunications towers that are exposed to these hazards, while Table 5.5 shows the percentage distribution of these towers situated in areas across the state with moderate to high hazard susceptibility.

Table 5.5: Number of towers exposed to multi-hazards in Tamil Nadu

Hazard	Towers (%)	No. of towers
Flood (very high, high, and medium)	33	16,113
Cyclonic wind (very high and high)	57	27,690
Landslide	1	516
Storm surge (>6 m)	14	6,796

Odisha

Odisha is a coastal state in eastern India. The state is prone to various natural hazards, including floods, storm surges, cyclonic winds, earthquakes and landslides. Being a coastal state, Odisha experiences a significant risk from cyclonic winds and has witnessed many severe cyclonic events in the past. There are 14 Odisha districts that are very highly susceptible to cyclonic wind. Among these, Khordha, Cuttack and Balasore have the maximum number of telecommunications towers exposed to such intense winds. While landslides are uncommon in Odisha and pose a very low risk to telecommunications towers, the districts of Balasore, Bhadrak, Kendraparha and Jagatsinghpur are susceptible to storm surges greater than 6 m and have the largest number of telecommunications towers at risk from storm surges. Ten districts of Odisha are susceptible to floods. The Balasore, Jajapur and Kendraparha districts have the highest number of telecommunications towers exposed to flood.

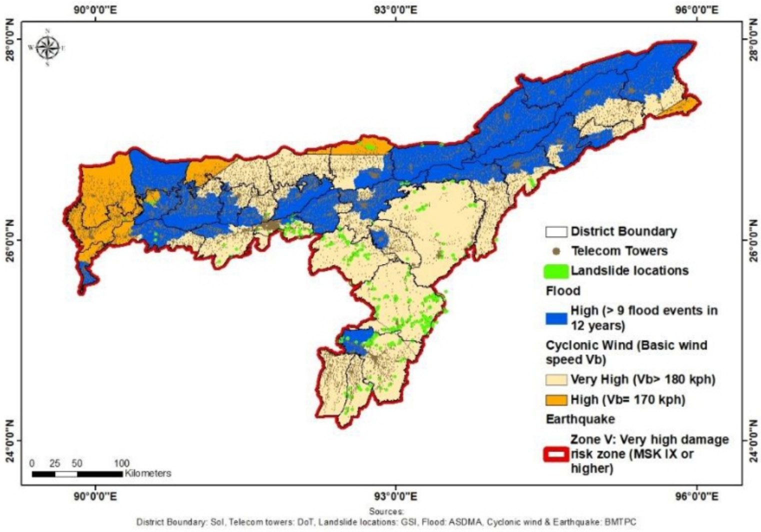


Figure 5.11: Multi-hazard exposure mapping of telecommunications towers: Odisha

Figure 5.11 depicts the mapping of 26,919 telecommunications towers that are exposed to these hazards, while Table 5.6 shows the percentage distribution of these towers situated in areas across the state with moderate to high hazard susceptibility.

Table 5.6: Number of towers exposed to multi-hazards in Odisha

Hazard	Towers (%)	No. of towers
Flood	13	3,843
Cyclonic wind (very high and high)	57	15,406
Earthquake zone III	36	9,666
Landslide	<1	9
Storm surge (>6 m)	14	3,788

Gujarat

The western state of Gujarat is prone to several hazards due to its coastal geography. This makes the region vulnerable to severe cyclonic storms, storm surges, earthquakes, landslides and floods. Fourteen districts of Gujarat are particularly susceptible to very high cyclonic winds, which pose a significant threat to telecommunications towers. Kachchh, Jamnagar and Bhavnagar have the highest number of these telecommunications towers exposed to very high cyclonic wind. The Bhavnagar and Amreli districts have the highest number of telecommunications towers at risk from storm surges. Ahmedabad, Gandhinagar and Banaskantha are highly susceptible to flooding, with a large number of telecommunications towers at risk. Additionally, four districts near the Maharashtra border are susceptible to landslides, though the threat to telecommunications towers in these areas is low. Valsad and Dangs districts have the most telecommunications towers exposed to landslides.

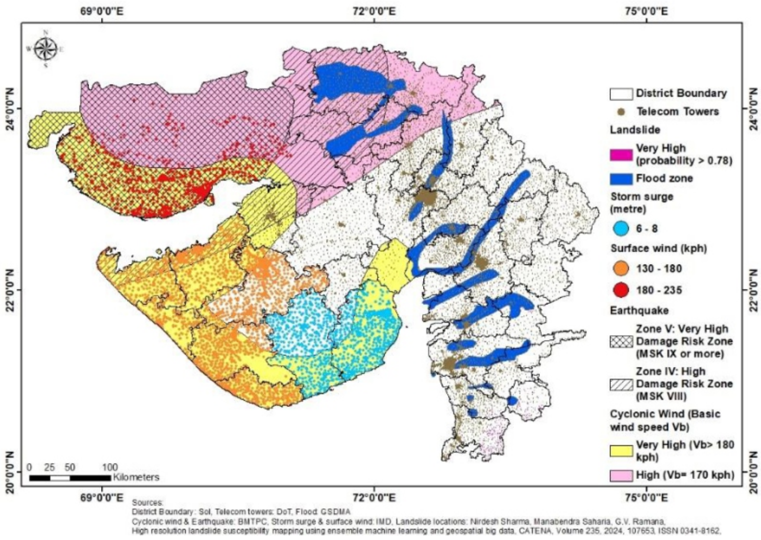


Figure 5.12: Multi-hazard exposure mapping of telecommunications towers: Gujarat

Figure 5.12 depicts the mapping of 45,249 telecommunications towers that are exposed to these hazards, while Table 5.7 shows the percentage distribution of these towers situated in areas across the state with moderate to high hazard susceptibility.

Table 5.7: Number of towers exposed to multi-hazards in Gujarat

Hazard	Towers (%)	No. of towers
Flood	12	5,512
Cyclonic wind (very high and high)	28	12,650
Earthquake zones IV and V	12	5,653
Landslide	2	1,093
Storm surge (>6 m)	5	2,520

5.4. Multi-hazard risk mapping at district scale

GIS mapping of OFC across Jamnagar and Dwarka districts, Gujarat

A GIS mapping of the OFC network has been conducted to assess its exposure to heavy rainfall, storm surges and earthquakes. This data was provided by the District Disaster Management Authority (DDMA) of Jamnagar. Located in seismic zone IV, Jamnagar is affected by storm surges ranging from 2.5 to 6 m and experiences over 17 days of heavy rainfall annually. Figure 5.13 illustrates the multi-hazard risk map of the OFC network at the district level. This map is a valuable tool for planning space-based telecommunications arrangements in the region.

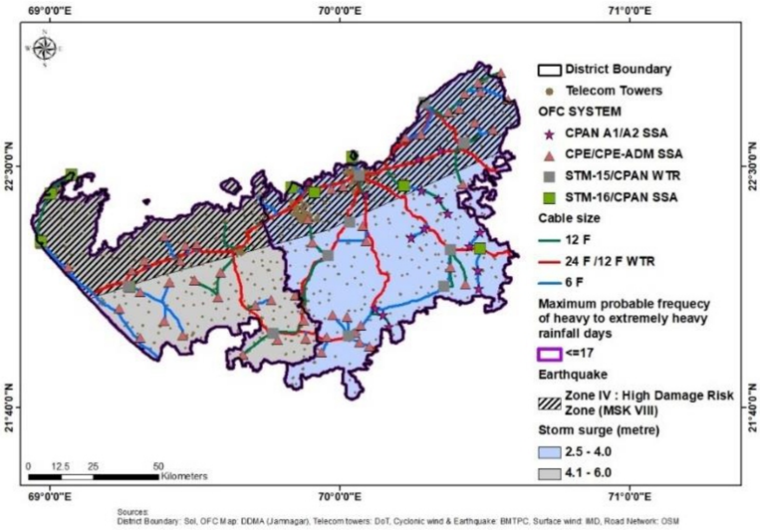


Figure 5.13: Multi-hazard exposure mapping of OFC cable: Jamnagar and Dwarka districts, Gujarat

Table 5.8: OFC network exposed to multi-hazard in Jamnagar and Dwarka districts, Gujarat

Districts	OFC network (%) exposed to multi-hazard	Total OFC network length (km)
Jamnagar	46	740
Devbhumi Dwarka	45	393

GIS mapping of telecommunications towers susceptible to landslide hazard across Rudraprayag district, Uttarakhand

The Rudraprayag district in Uttarakhand is highly susceptible to landslides and is located within seismic zones IV and V. Each year, the district endures significant damage and loss of infrastructure and life. Using data from the DDMA of Rudraprayag, a GIS mapping of telecommunications towers exposed to landslide hazards has been conducted. Figure 5.14 presents the landslide hazard risk map for telecommunications towers at the district level. This map serves as a crucial tool for planning and designing the foundations of telecommunications towers in areas with high landslide risk.

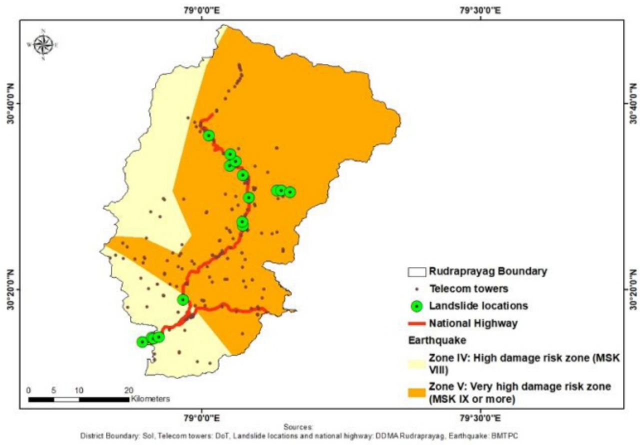


Figure 5.14: Multi-hazard exposure mapping of telecommunications towers: Rudraprayag district, Uttarakhand

Table 5.9: Number of towers exposed to landslide and earthquake zone V in Rudraprayag district, Uttarakhand

Districts	Telecommunications towers (%) exposed to landslide and earthquake zone V	Total number of towers
Rudraprayag	13	198

GIS mapping of power and telecommunications assets exposed to multi-hazards across Nowboicha Tehsil under Lakhimpur district, Assam

Assam is highly susceptible to perennial floods, and Nowboicha tehsil in the Lakhimpur district is particularly vulnerable due to its location within high-risk areas for floods, cyclonic winds and seismic zones. These hazards frequently affect interconnected infrastructure such as power, roads and buildings, leading to cascading impacts on the availability of telecommunications services across the region. Utilizing data from the Assam Power Distribution Company Limited (APDCL), Assam State Disaster Management Authority (ASDMA) and the DoT, Government of India, a GIS mapping of telecommunications towers exposed to these hazards has been conducted. showcases the multi-hazard risk map for telecommunications towers at the tehsil (block) level. This map is an essential tool for planning and designing a redundant infrastructure system to ensure the continuity of telecommunications services during disasters.

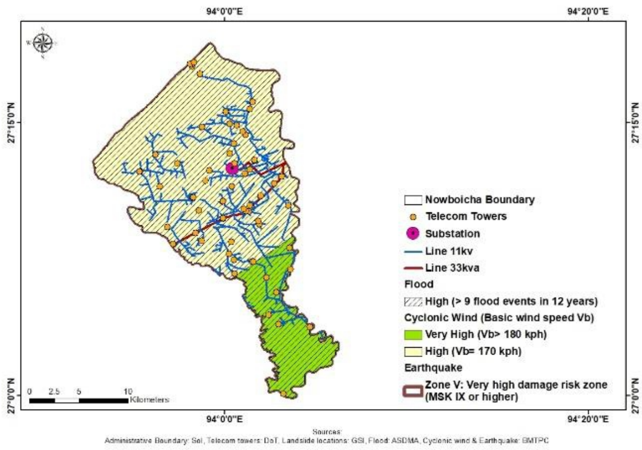


Figure 5.15: Multi-hazard exposure mapping of telecommunications towers: Nowboicha tehsil, Assam

Table 5.10: Number of towers exposed to multi-hazard (earthquake V, high flood, high cyclone) in Nowboicha tehsil, Assam

Districts	Telecommunication towers (%) exposed to multi-hazard (earthquake zone V, high flood high cyclone)	Total OFC network length (km)
Nowboicha	8	68

6. Transforming catastrophe into continuity: A disaster resilience framework

6.1. Unlocking disaster resilience

A disaster resilience framework is essential for enhancing preparedness, reducing vulnerabilities and facilitating the rapid recovery of infrastructure following disasters. The Sendai Framework for Disaster Risk Reduction (2015-30) serves as a global blueprint to minimize disaster-related losses in terms of lives, livelihoods and infrastructure. Resilience frameworks consist of concepts and practices developed based on practical evidence and experience. They encompass strategies, services and mechanisms designed to improve the overall resilience posture. Most frameworks are designed to bridge the gap between strategic and operational levels, ensuring that high-level policies are effectively implemented at the grassroots level. Conversely, operational-level frameworks focus on local contexts and stakeholder-driven initiatives, providing practical tools and strategies tailored to the specific needs and conditions of local communities, businesses and infrastructure.

The following section of this chapter offers a comprehensive assessment of various resilience frameworks, detailed in Annexure 4: Details of global resilience framework, of this document, exploring their components and unique approaches to addressing disaster risk and resilience, ensuring adaptability and reducing vulnerabilities.

6.2. Key insights from global resilience frameworks

The insights presented in this review go beyond a mere compilation of information; they represent a concerted effort to contribute to developing a robust framework for assessing disaster risk and resilience within the telecommunications infrastructure system. This review also highlights innovative approaches to resilience, such as integrating advanced technologies, promoting social inclusivity and adopting a system-scale perspective. A thorough examination of resilience frameworks underscores the crucial role of system capacity, effective process management and strong stakeholder engagement in mitigating disaster impacts and fostering resilience. Consequently, a strategic approach to enhancing resilience involves planned interventions at the asset, network and system levels throughout all phases of the disaster cycle—pre-event preparedness, during-event response and post-event recovery. The frameworks reviewed take a multi-dimensional approach, recognizing that critical infrastructure systems often encompass multiple resilience parameters. To navigate this complexity, a layered response emerges as the optimal structure, allowing for the independent modification and analysis of individual components while maintaining their interconnectedness to ensure a comprehensive assessment. Furthermore, the comparative analysis of these frameworks emphasizes the importance of considering the inherent interdependencies within critical infrastructure systems and the significant impacts that may arise from unanticipated current and future climate change. Table 6.1 gives a brief description of the reviewed global resilience frameworks.

Table 6.1: Brief description of the reviewed global resilience frameworks

Framework	Relevant Critical Infrastructure (CI) coverage	Scale	Unique features relevant to the DRRAF
Infrastructure Resiliency: A Risk-Based Framework, 2013[49]	All critical infrastructure	Regional	The framework uses a risk-based layered defence, which analyzes the likelihood and potential severity of threats and adopts a multiple-layer approach to mitigate risks. It emphasizes resilience throughout the entire infrastructure lifecycle.
Infrastructure resilience: De-risking transport infrastructure projects in India, 2023[50]	Transport infrastructure	National	A structured risk-resilience framework helps address operational blind spots in infrastructure projects through proactive risk management tailored to different sectors and leveraging data for risk assessment.
Future-proofing energy systems: The Energy Resilience Framework, 2019[51]	Energy	Global, National, Subnational, Regional and Local	Customizes energy resilience solutions to specific needs, ensuring diversity, redundancy, flexibility and adaptability, and adapt using valuable lessons learned for further improvement. It also assesses critical infrastructure resilience and establishes supportive policies and regulations.

Framework	Relevant Critical Infrastructure (CI) coverage	Scale	Unique features relevant to the DRRAF
DFID's Disaster Resilience Framework[52]	All critical infrastructure	Countries, communities, and households	Resilience-building strategies should be tailored to the specific context, focusing on proactive measures, reliable funding, and integration into broader development and humanitarian aid efforts.
Infrastructure Resilience Planning Framework (IRPF), 2022[53]	Communication, transport, energy, water/wastewater system	National, subnational, regional and territorial government, and organizational	The framework highlights community benefits by identifying potential hazard impacts, preparing to withstand, adapt to, and mitigate evolving threats, integrating infrastructure resilience into planning and implementation, and recovering quickly to return to normalcy.
Critical Infrastructure Resilience Index (CIRI), 2017[54]	All critical infrastructure	Organizational and technological	The index establishes relationships between key performance indicators (KPIs) and system operations, highlighting targeted resilience measures, pre-crisis mitigation, post-crisis evaluation, monitoring and response, restoration, reconstruction and recovery.
DHS Resilience Framework, 2018[55]	Energy, water, information and communication technology and transportation	National and subnational	The framework provides detailed guidance to the stakeholders for conducting a criticality assessment, assessing liabilities, identifying resilience gaps, devising resilience solutions and integrating resilience solutions to strengthen infrastructure resilience.
USAID's Climate-Resilient Development, 2014[56]	Energy, transportation, water resources, communications and other sectors	Global	The framework addresses climate change impacts, enhances adaptation capacity, integrates climate considerations into development planning and encourages collaboration among stakeholders. It advocates adaptive management, allowing adjustments based on new information and changing conditions.
The PEOPLES Resilience Framework, 2013[57]	Utilities, social/community	Government services and community	This framework suggests monitoring social and community resilience at the following scales: Global, national, regional and local.
The Climate Resilience Framework, 2014[58]	All critical infrastructure	Regional	The framework evaluates climate vulnerabilities and risks, even accounting for uncertainties, and can address emerging, indirect and slow-onset climate impacts and hazards.
Resilience Framework of Critical Infrastructure (EU-Circle), 2018[59]	Energy, industry, water, transportation, and information and communication technology	National, subnational, local government and organizational	The resilience framework assesses four key layers: climate hazard and parameters, critical infrastructure and interdependencies risks and impacts from climate change, and the capacity of critical infrastructure to withstand, respond, recover and strengthen resilience.
Vulnerability to Resilience (V2R) Framework, 2011[60]	All critical infrastructure	Individuals, households and communities	The framework helps analyze and address vulnerabilities by identifying key factors: exposure to hazards, fragile livelihoods, future uncertainty and weak governance. It also helps to analyze linkages between these factors and develop ideas for action to strengthen resilience.

6.3. Disaster Risk and Resilience Assessment Framework

CDRI's Disaster Risk and Resilience Assessment Framework (DRRAF) is designed to provide a comprehensive guide for stakeholders to understand and address current and future risks affecting infrastructure systems. At present, there is a notable absence of a holistic framework specifically tailored to guide telecommunications stakeholders in integrating disaster resilience into their operations. DRRAF aims to fill this gap by enhancing the processes of identifying, assessing and mitigating various disaster risks while also developing strategies to bolster resilience within telecommunications infrastructure systems. This proposed framework aligns with and complements various global resilience frameworks, ensuring a cohesive approach to disaster risk management and resilience building internationally. Below are some of the unique features of the framework.

- Considers **multi-hazard cascading** and **compounding impacts**
- Strengthens resilience at asset, network and system levels, **identifying the weakest element**
- Selects **optimal resilience interventions** (cost-effective, technically feasible, socially acceptable and nature-friendly)
- Records periodic and event-based changes to **adapt to dynamic vulnerabilities**
- **Learns through monitoring** and **evaluation** of each disaster event impacts

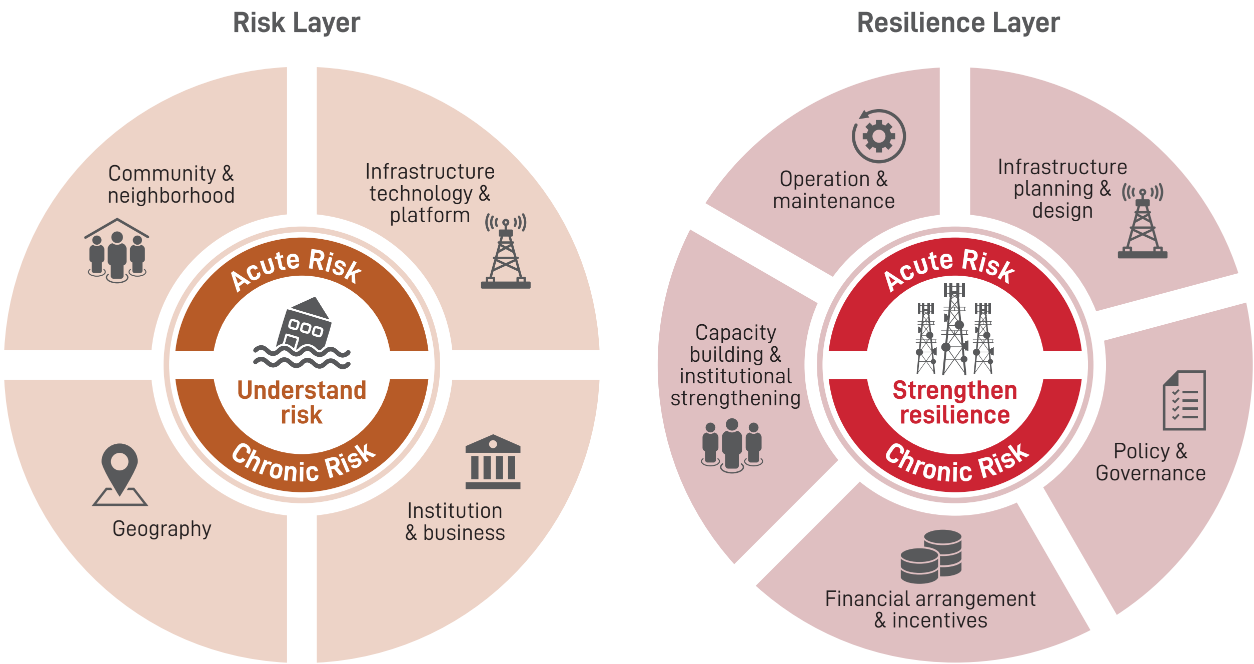


Figure 6.1: Disaster Risk and Resilience Assessment Framework

6.3.1. Building blocks of DRRAF

The DRRAF consists of two interactive layers: the risk layer and the resilience layer. The risk layer maps both acute and chronic hazards, infrastructure, institutions and communities across various geographies. It provides stakeholders with insights into the system's coping capacity at different levels of risk and identifies the system's weakest element. The resilience layer offers an in-depth analysis of necessary changes in systemic elements, considering the dynamically changing nature of disaster vulnerabilities. It also suggests mechanisms for monitoring and evaluation, enabling learning and adaptation as vulnerabilities evolve over time.

- **Risk layer:** The risk layer assesses the risk profile of telecommunications and its interconnected infrastructure system.
- **Resilience layer:** The resilience layer identifies and prioritizes various resilience options and assesses the cost of inaction and the benefits of investments in resilience.

The framework can be applied to periodic and event-based changes across diverse geographic areas and all aspects of telecommunications infrastructure systems. Risk information from the risk layer serves as input for the resilience layer, while insights from the resilience layer provide feedback to the risk layer, helping to identify emerging risks over time.

Components and sub-components of the risk layer

Map infrastructure and hazards: This component identifies and maps infrastructure, technologies, stakeholders and hazards across all three miles in various geographies.

Identify telecommunications infrastructure, its interconnectedness and interdependency	Identify and map telecommunications infrastructure both wired and wireless, and the interconnected infrastructure systems such as power, road and buildings
Map the linkages, critical nodes, technologies and redundancies	Map the linkages through wire/wireless connections; critical nodes such as MSC; NoC; Data Centre; technologies 2G-5G and beyond; alternate technologies such as SATCOM, HAM, radio communications; and redundant infrastructure such as Cell on Wheel, Mobile Exchanges, Micro Grids and networks such as ring or mesh network
Map the stakeholder	Map all key stakeholders such as TSPs/ISPs/IPs, LSA, State Disaster Management Departments, SDMA, DDMA, power and buildings, roads, etc.
Map the telecom subscribers across geographies	Map the telecom subscriber base (wireless and wireline subscribers, etc.) residing across geographies
Map shocks and stresses (existing and potent)	Map the natural hazards under the following three categories: geo-physical, hydrological and meteorological for the selected geographies
Assess the degree of dependencies	Assessing the degree of interdependencies of other infrastructures assessing the cascading and compounding impacts

Assess system state: This component looks into the hazard, risk and vulnerability assessment of the Indian telecommunications sector to identify the weakest elements across the system.

Map the exposure elements	GIS mapping of the exposed infrastructure under various hazards into consideration
Assess vulnerability and risk the exposure elements	Develop vulnerability functions considering the structural (such as material specifications, age, etc.) and hazard parameters (such as intensity, duration, frequency and spatial extent); carry out a risk assessment
Assess the coping capacity of systemic elements	Assess on-ground condition of exposed elements (such as telecommunications towers, poles and road networks) against natural hazards by considering damage pattern and degree of loss
Identify the weakest elements across the system	Identify the most vulnerable telecom infrastructure system elements based on the results obtained through the hazard, risk, and vulnerability assessment

Components and sub-components of the resilience layer

This section focuses on identifying, prioritizing, and finalizing the resilience solutions to strengthen the telecommunications sector's resilience.

Identify prioritize resilience options under five dimensions	Identify the resilience options that are cost-effective, nature-friendly, technically viable and socially acceptable under five dimensions, viz. policy, institutions and processes (PIPs), technical planning and design, operations and maintenance, financial arrangements and expertise/capacity enhancement. Prioritize the resilience options based on cost-benefit analysis of different resilience measures considering the following parameters such as risk state, dynamic vulnerability, asset's lifecycle cost and socio-economic benefit

Monitor, learn, update and adapt

Monitor the performance of the system	Cyclic and event-based - This involves the process of monitoring the performance of the system, capturing and updating the learnings, upgrading the system capacity and adapting to the change
Capture the learnings and update the information regarding vulnerability, sensitivity, risk and impact	Capture learnings from managing recent disasters
Update the system capacity	Update the information across the system and stakeholder
Adapt with the change	Enhance system capacity to adapt with dynamic change through technological advancements and sharing information across the peers

6.4. Datasets for disaster risk and resilience assessment

Table 6.2: Datasets for disaster risk and resilience assessment

Risk layer	Datasets
Hazard	Multi-hazard dataset at district and sub-district scale
Exposure	GIS datasets of telecommunications and interconnected/interdependent assets for all three miles
Vulnerability	Sensitivity, susceptibility and damageability/damage function of assets due to multi-hazard exposure
Capacity	Absorptive, coping, restorative and adaptive capacity of the system under consideration
Risk	Loss and damage of life, infrastructure, demography, services and consumers, business, livelihood, productivity, learning hours, supply chain, information, income/wages, health, transportation, etc.
Resilience layer	
Infrastructure system	Infrastructure owners and tenants, cost, lifecycle, types, technical standard, certification, geospatial network maps
Operation and maintenance	Periodic maintenance details, corrective and preventive actions (CAPA), asset inventory details, service contracts
Policy and governance	Policy, guidelines, SoPs and action plans of the sector
Capacity building and institutional strengthening	Knowledge gap assessment, training and skill development need, capacity building plan, stakeholder engagement plan
Financial arrangement and incentives	Viability gap funding, grants, revenue model, insurance options, and risk-sharing instruments

6.5. Disaster risk and resilience index for selected five states (considering five domains and nine resilience parameters)

Disaster risk is a function of hazard, vulnerability and intrinsic capacity of any system. It is commonly defined as:

Disaster Risk = Hazard (H) x Vulnerability (V) / Capacity (C)

The Disaster Risk Index (DRI) for an infrastructure system is a comprehensive tool for identifying and assessing disaster risks. It analyzes both the likelihood of hazards and their potential impacts on infrastructure. This index incorporates a range of geographical and socio-economic factors to accurately evaluate vulnerability and impacts. It also monitors the evolution of risk within the infrastructure system for each hazard type according to their degree of exposure.

The DRI serves as a vital tool for informing policy changes, infrastructure planning and design, operational procedures, maintenance strategies, capacity building and financial investments. It establishes a benchmark for evaluating a system's effectiveness under various disaster scenarios. The index incorporates key indicators, including good governance, learning capacity, resourcefulness, flexibility, responsiveness, redundancy, robustness, information flows, safe failure and interdependency. By assessing these factors, the index monitors a system's ability to adapt, manage and respond effectively to disasters.

This section outlines a systematic approach followed to develop the disaster risk and resilience index for five selected states.

Methodology for risk index development

The risk index for the telecommunications infrastructure system has been developed by evaluating the local hazard exposure of telecommunications assets across each state. Geospatial analysis has been employed to estimate the exposure of these assets to varying levels of hazard severity. The risk index is divided into six categories, each reflecting a different level of hazard severity and the percentage of assets located within these zones. An ordinal scale assigns a risk score based on the range of asset exposure percentages, providing a clear risk index. Figure 6.2 represents the hazard risk index of five selected states and Figure 6.3 represents the hazard severity scale and its corresponding risk score.

State Hazard	Risk Index for telecommunications assets						
	Earthquake	Cyclone wind	Flash flood	Flood	Landslide	Storm surge	Forest fire
Assam							
Uttarakhand							
Gujarat							
Odisha							
Tamil Nadu							

Figure 6.2: Hazard risk index of five selected states

Exposer of assets (%)	Risk score	Hazard severity
0	0	No hazard/Data not available
1-20%	1	Very low
21-40%	2	Low
41-60%	3	Moderate
61-80%	4	High
81-100%	5	Very High

Figure 6.3: Hazard severity scale and its corresponding risk score

Methodology for risk index development

The resilience index for the telecommunications infrastructure system was developed by assessing various resilience key performance indicators (KPIs) across each state. These KPIs were evaluated based on feedback from stakeholders, collected through focus group discussions (FGD) and key informant interviews (KII) conducted during field consultations in the three most vulnerable districts, as well as three blocks in each selected state. Each response was weighted equally across the different KPIs. Further, ranks were assigned between 0 and 5, where a score of 0 indicates that the system is not resilient, while a score of 5 indicates that the system has inbuilt resilience. The resilience score has been estimated using the weighted average of each KPI individual score as shown below:

$$\text{Resilience KPI score (RS)} = \sum_{i=1}^{n} a_i * w$$

where a_i is the normalized average rank for the selected blocks against ith question and w is the weight assigned to each question.

The combined resilience score of the state was estimated by summing each KPI score as shown below:

$$\text{Resilience Index (RI)} = \sum_{i=1}^{10} RS_i$$

where RS_i is the resilience score for the ith KPI.

Figure 6.4 represents the system with a low resilience score to a system with a high resilience score and Figure 6.5 represents the resilience index of five selected states.

Resilience score	
0	No data
1	Rare, Very low
2	Low sometimes
3	Often moderate
4	Likely, high
5	Always, very high

Figure 6.4: System with low resilience score to system with high resilience score

Resilience KPIs	Assam	Gujarat	Tamil Nadu	Odisha	Uttarakhand
Good governance					
Capacity to learn					
Resourcefulness					
Flexibility					
Resposnsiveness					
Redundancy					
Robustness					
Information Flows					
Safe Failure					
Interdependancy					

Figure 6.5: Resilience index of the five selected states

7. Recommendations

7.1. Recommendations

This section outlines several recommendations for national and sub-national stakeholders across five domains: (i) Policy, (ii) Planning and Institutions, (iii) Technical Planning and Design, (iv) Operation and Maintenance, Financial Arrangements, and Incentives, and (v) Expertise. These recommendations will guide the stakeholders in developing short-, medium- and long-term roadmaps to strengthen disaster resilience across the sector at a system scale.

Recommendation 1: Enhance technical planning and design to withstand disaster impacts

- There are increasing service availability issues across highly disaster-vulnerable regions and rural areas due to inadequate redundancy in network planning and limited availability of emergency communication devices. **Hence, there is a need to carry out a comprehensive need assessment for adding redundancy in the network, pre-positioning of Cell on Balloon, Cell on Truck, Cell on Ship and Boat, High Altitude Platform System (HAPS), procuring emergency communication devices, and restore landline phones based on historical and forecasted hazard risk information.**
- There is limited Cell on Wheels (CoW) available across states and with operators. **Hence, the DoT may maintain an appropriate number of CoWs centrally and may deploy them as per the requirements across the country.**
- Island blocks face unique geographical challenges that impede reliable middle-mile connectivity. **Therefore, allocate dedicated satellite bandwidth for these regions and connect such geographies through a backhaul network to ensure seamless connectivity.**
- Submarine cables face increasing risk of cuts due to coastal erosion and high-intensity coastal hazards. **Multiple cable landing zones should be planned across coastal states to ensure better first-mile network redundancy.**
- Twenty-seven percent of telecommunications towers across the country are highly vulnerable to earthquakes. **Strengthening the seismic resilience of these assets is essential to mitigate risk and ensure network stability.**
- Twenty-seven percent of telecommunications towers are vulnerable to high earthquake hazards across the country. **There is a need to ensure sufficient seismic resilience to these assets.**
- Telecommunications infrastructure in coastal regions is highly susceptible to cyclonic winds and storm surge of varying intensity. To strengthen the resilience of this infrastructure. **There is a need to enhance the design of this infrastructure, which can withstand wind speeds of up to 300 kmph within a 20 km radius of the coastline.**
- Telecommunication infrastructure damage and loss are increasing across geographies. There is a need to assess the disaster risk of these infrastructures comprehensively. **Hence, site selection considering probabilistic hazard risk modelling scenarios should be undertaken prior to the installation of telecommunication assets.**
- Due to massive influx of devotees in pilgrimage of national /international importance (Puri & Chardham) there is a recurring issue of network congestion/ service unavailability in the region. **Hence, there is a need to plan and prepare for robust telecommunication service availability though alternate telecommunication technologies using dedicated bandwidth and through dynamic traffic management leveraging the data communication, satellite communication, radio communication, and edge computing.**
- Interoperability challenges exist across different generations of telecommunication devices. **To address this,low latency wireless communication of 10-20 milliseconds (ms) (down from the existing 250 ms) should be implemented to sync with next-generation LEO satellite communication technologies (having latency between 2 and 27 ms).**
- Data Centres (DC) requires a large amount of uninterrupted power throughout the year. Frequent damage to power infrastructure due to disasters may have a cascading impact on their operations. **To mitigate this risk, captive power supply must be planned through two feeder lines located i different hazard zones.**
- The lack of dedicated duct available along the district/sub-district road network for laying telecommunications cables leads to frequent damage. Establishing **a common duct for infrastructure a cost-sharing basis with operators may help reduce the frequent damage of OFCs.**
- There is an interoperability issue across different-generation telecommunications devices. **There is a need to provision for low latency (10-20 ms from the existing 250 ms) wireless communication to sync with next-generation LEO satellite communication technologies (having latency between 2 and 27 ms).**
- DC requires a large amount of uninterrupted power throughout the year. Frequent damage to power infrastructure due to disaster may have a cascading impact on the DC operation. **A captive power supply in the DC must be planned through two feeder lines falling under different hazard-vulnerable zones.**
- There is an insufficient dedicated duct available along the district/sub-district road network for laying telecommunications cables, which leads to frequent damage of these cables. **The provision of a common duct across this region on a cost-sharing basis with operators may help reduce the frequent damage of OFC cuts.**

- The Draft Data Centre Policy 2020 emphasizes that Data Center buildings require different norms compared to typical office or commercial structures. Therefore, creating a unique category code for Data Center in the National Building Code 2016 is essential.
  Hence, it is required to recognize Data Center as a separate category under the National Building Code.

Recommendation 2: Develop robust multi-hazard information repository for the sector

- The reporting format of State Disaster Response Fund (SDRF) does not include telecommunications department damage loss information, and there is limited historical multi-hazard damage and loss information available for the sector.
  Mainstreaming disaster data collection using updated data format may help develop a robust multi-hazard data repository for the sector.
- There are limited multi-hazard zonation maps available across a state and at a sub-district scale, and these maps have limited information on hazard intensity, frequency, and duration.
  Hence, there is a need to develop standard and updated multi-hazard zonation maps across all states up to the sub-district scale.
- There is no comprehensive assessment to identify the critical telecommunication assets that may provide minimum service connectivity during a disaster.
  Hence, there is a need to carry out a comprehensive assessment to identify such critical infrastructure at a sub-district scale that may provide the required connectivity.
- Network/service unavailability during disasters are rising across the country and the current Quality of Service (QoS) parameter does not precisely account the disaster resilience of each network element.
  A multi-hazard, multi-geography network resilience index is needed to assess and strengthen systems to scale.

Recommendation 3: Risk informed governance across the sector

- Due to limited disaster risk information available at the local scale, there is inadequate disaster preparedness.
  Increasing the accuracy and scale of hazard forecasting and mainstreaming disaster risk modelling for location-specific risk understanding may help in risk-informed governance across the sector.
- Building susceptibility to multi-hazard often leads to damage to Roof Top Towers (RTT).
  Ensuring the building codes consider multi-hazard impacts may help reduce the vulnerability of RTT due to building failure.
- There is a limited mechanism to validate telecommunications asset damage loss information provided by the operators.
  A disaster task force at each LSA level must be formed to validate damage loss information.
- There is a limited understanding of disaster vulnerability and risk of telecommunications infrastructure system among the stakeholders, which restricts effective preparedness and impacts restoration activities at the local scale.
  A disaster resilience lab should be set up at the national level under the guidance of the National Communication Academy (NCA) to support robust decision-making.
- There is an increasing issue of community violence due to poor network and service availability during disaster. **Hence, there is a need to upgrade the 'Sanchar Saathi' portal to register and address consumer grievances online during disaster.**
- Adoption and enforcement of the National Building Code across the country.
  Effectively implement the code by local authorities particularly given the complexities of ICT infrastructure, to realize their intended benefits.

Recommendation 4: Develop a cross-sectoral framework and leverage partnerships for stakeholder collaboration

- There is no knowledge-sharing platform that can guide stakeholders in improving collaborations to better manage the disaster collectively.
  There is a need to establish a countrywide knowledge platform to exchange disaster management learnings.
- Power outages have a significant cascading impact on telecommunications service continuity.
  Developing a framework to ensure uninterrupted power supply to critical telecommunications sites through alternate power arrangements such as renewable energy and microgrids can help manage the disaster and restore the services effectively.
- There is a lack of dedicated telecommunications infrastructure at critical industrial locations/parks/zones and multipurpose disaster shelters across the country.
  Developing a framework to establish a dedicated telecommunications infrastructure system at these locations may help establish better connectivity during a disaster. For dedicated telecommunications services, a premium tariff may be charged to the consumers.

Recommendation 5: Increase financial arrangements for strengthening infrastructure resilience

- There is limited financing support available for strengthening the resilience of infrastructure systems across the country.
  Assessing the need for resilience building and provisioning the budget for the financial planning of the line departments may help reduce infrastructure damage and loss and consequent economic loss.
- There is limited terrestrial network bandwidth availability in the mountainous regions.
  Extend financial support through USOF/Digital Bharat Nidhi to establish SESG to provide connectivity to the mountainous region through the LEO satellite constellation in the future.

Recommendation 6: Develop risk-sharing instruments for telecommunication operators

- There is no risk-sharing instrument available for derisking the telecommunication operators.
  The parametric insurance model may extend the risk-financing support to the operators.

Recommendation 7: Promote last-mile connectivity and information access

- There are insufficient communication channels for sending disaster warnings/alerts and restoration updates to last-mile residents in remote locations.
  It is required to make a provision to provide each 'Aapda Mitra' volunteer, village head, Anganwadi leader, postman, etc., with alternate communication devices, such as shortwave radio communication devices to establish last-mile connectivity and support information access to them.
- There is limited bandwidth available for disaster communication in remote areas.
  Extending the inter-band spectrum sharing for such regions may improve emergency communication.
- There is a limited connectivity provision in non-feasible regions.
  The DoT may provide funding support to operators for setting up an asset in the non-feasible regions through the bidding or nomination process. Other operators may latch based on the tariffs defined by TRAI. Additional spectrum may be allocated during emergency situations.

Recommendation 8: Leverage collaborative and digital efforts to strengthen service restoration activities

- There is limited logistic support available to the telecommunication operators from the local administration.
  Priority support and arrangement of fuel, power and transportation may help strengthen better restoration activities.
- There is a cumbersome approval process for telecommunications service restoration activities.
  Making a single-window digital permission system provision may expedite the restoration activities.
- There is limited spatial information available about the optical fibre network damage.
  GIS mapping of the countrywide OFC cable network and integrating it with a real-time fault management system may help restore the services faster.
- There is a significant delay in submarine cable repair due to the multi-stage approval process. This may result in a major connectivity blackout in the future.
  There should be a provision for specialized Indian shipping vessels to repair the submarine cables to expedite the restoration activities.
- There is significant lack of earthquake/landslide warning systems across the country. Earthquake/landslide events are geo-physical in nature and most of the OFC cables are buried underground. If these cables networks are used as a sensor/platform to monitor sub-surface/ geo-physical activities, this can help predicting these geo-physical events with reasonable lead time.
  Hence, OFC cable network can be leveraged for disaster prediction and warning dissemination.
- There is a significant delay in submarine cable repair due to the multi-stage approval process. This may result in a major connectivity blackout in the future.
  A provision for specialized Indian shipping vessels to repair the submarine cables can expedite the restoration activities.

Recommendation 9: Upscale institutional capacity and improve last-mile expertise

- There is a consumer knowledge gap at the last mile for ICR service activation.
  Community awareness programmes may help improve the last-mile capacity to avail of these services.
- There is insufficient manpower in rural areas for preventive maintenance and restoration work.
  Upscaling institutional capacity through comprehensive resource need assessment for these activities at the block/district level may improve the operational resilience of the system.
- Availability and usage of satellite phones across line departments are limited due to their high cost, complex handling, and limited function in indoor/denser regions.
  It is necessary to provide user-friendly, cost-effective satellite phones for line departments supporting disaster management activities.

Recommendation 10: Improve the service quality through precise monitoring mechanism

- There is a frequent issue of call connectivity and network congestion during the golden hour of disaster. There is also limited information available from the DoT on the number of call attempts made by telecommunications subscribers in the impacted regions.
  Daily/weekly monitoring of call traffic, dropped call rate (DCR) and cell bouncing busy hours at the district scale rather than the LSA scale may help assess the service quality across the disaster-impacted regions.
- Assessment of telecommunications faults is carried out on a monthly basis, which does not precisely account for the restoration efficiency during a disaster.
  The mean time to repair (MTTR) should be accounted for every week rather than monthly to assess the fault repair comprehensively.

7.2. CBA of selected recommended measures

Cost-benefit analysis (CBA) is a technique for evaluating the economic feasibility of various options. This technique includes measurement and comparison of the total projected costs of an option against its total projected benefits to determine the net benefits. It is essential for infrastructure resilience investment, as it provides a quantitative basis for the economic justification of investments. Additionally, it facilitates the comparison of different strategies, helping decision-makers choose the most effective options. By attempting to incorporate intangible benefits like public safety and environmental protection, CBA strengthens the case for resilience investments, ensuring decisions are both economically sound and strategically effective.

There are different types of CBA methods that can be applied based on the project stages.

- **Ex-ante CBA:** This analysis is performed before implementing a project or policy. It aids in predicting the anticipated costs and benefits of a proposed action to evaluate its feasibility and economic viability.[61]
- **Ex-post:** This analysis is performed after a project or policy has been implemented; this analysis assesses the actual costs and benefits incurred. It is valuable for evaluating the accuracy of initial forecasts and the effectiveness of the project or policy.
- **In media res:** This analysis is performed during a project's implementation, i.e., the project is already in progress. It incorporates the benefits of both ex-ante and ex-post CBA methods by influencing the ongoing project, similar to ex-ante CBA, and collecting data to guide future projects, as seen with ex-post CBA.

Multiple steps are involved to carry out comprehensive CBA. Different steps are presented Figure 7.1.

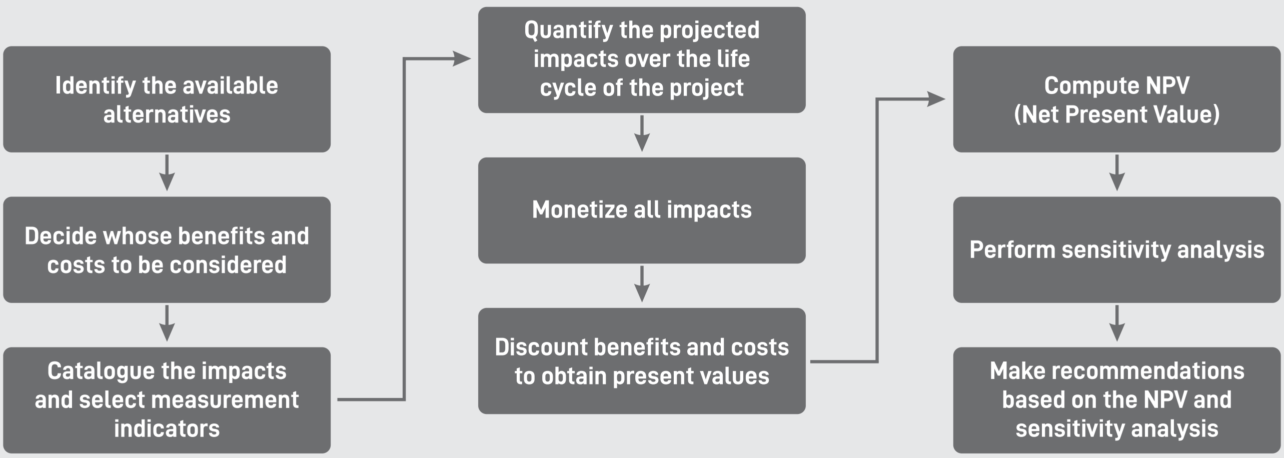


Figure 7.1: Steps to carry out CBA

Multiple steps are involved to carry out comprehensive CBA. Different steps are presented Figure 7.1.

CBA starts by identifying all viable alternatives and defining the relevant stakeholders. Next, the impacts of each alternative are catalogued, appropriate measurement indicators are selected, and projected impacts are quantified over the project lifecycle. These impacts are then monetized, and future values are discounted to present values. The net present value (NPV) is calculated for each alternative. Finally, a sensitivity analysis is performed to assess the robustness of the NPV calculations, and recommendations are made based on the NPV and sensitivity analysis results.

For the purpose of CBA, ex-ante CBA was done to understand the benefits of investing in the disaster resilience of telecommunications infrastructure system. This will help stakeholders to understand the risk in a project and assess the financial benefits of incorporating resilience measures. The following are some of the intended outcomes of cost-benefit analysis under this project;

1. Evaluate and compare the long-term financial implications of investing in disaster-resilient infrastructure versus conventional infrastructure
2. Aid decision-makers to identify the cost-effective measures for infrastructure strengthening
3. Quantify the costs and benefits associated with resilience interventions, including reduced disaster recovery costs and improved service continuity
4. Support informed policy and investment decisions

For the purpose of CBA under this project, ex-ante CBA was done to understand the benefits of investing in the resilience of telecommunications infrastructure systems. The key assumptions for conducting CBA are as follows:

- 25-35 percent of telecommunications towers can ensure basic connectivity in any district
- Districts may have 20-50 percent overhead telecommunications cables
- 20-40 percent of telecommunications sites are only connected with captive power across the district
- 1-2 percent of the tower gets damaged in highly impacted districts and incurs financial loss in the range of 1-2 percent

The following steps were undertaken based on the above assumptions;

1. **Development of hazard catalogue:** Cyclone hazard catalogue was developed to carry out the district-scale assessment. The catalogue was developed based on hazard data published (intensity, frequency, and districts impacted) in the public domain by respective government organisations. Cyclone hazard events of the last 40 years in the selected eastern and western coastal states (Tamil Nadu, Odisha, and Gujarat) of India were assessed for developing the catalogue. The catalogue has the following parameters to understand the severity of hazard and its spatial extent:

i. Type of hazard
ii. Year of occurrence
iii. Number of districts impacted
iv. Intensity of the hazard in standardized measurement units

2. **Damageability assessment:** To understand the damageability of various asset classes for a selected geography, asset damage and loss data of the last five years due to cyclone hazard were collated and assessed for selected highly impacted districts. Following parameters were assessed;

i. Asset damage (degree, unit)
ii. Cost of the damaged asset
iii. Annual O&M cost of the asset

3. **Disaster resilience intervention cost:** Selected resilience interventions such as replacement of severely damaged infrastructure and retrofit moderately impacted telecommunication infrastructure system such as heightening of the foundation, arrangement of additional power back-up (through generator, battery and RE), underground cabling, etc. were considered for assessing the cost of suitable resilience interventions. It also considered the percentage of required interventions for different asset category.

4. **Benefit analysis:** The benefit analysis considers reduced replacement and repair cost as well as saving of post-disaster recovery expenses. The benefit-cost ratio suggests about the benefits of investing in resilient telecommunication infrastructure system to its cost. The net present value (NPV) suggests about the net benefit over the infrastructure life cycle where as internal rate of return (IRR) suggest about the break even of net present value of cost and benefit.

The following formulas were applied for a comprehensive assessment of the cost and benefits parameters ;

Cost of Repair

The annual cost of repair is calculated by multiplying the damageability (expressed as the percentage of the asset impacted by the total project cost (Eqn. 1). The recovery needs over the project's life cycle are determined by multiplying the frequency of hazardous events by the cost of repair e ach year (Eqn. 2).

Cost of repair each year = Damagebility (% of asset impacted)*Totat project cost	**Eqn. 1**
Recovery needs over the project life cycle = Frequancy of Hazard*Cost of repair each year	**Eqn. 2**

Revenue loss

Revenue loss is calculated by multiplying the revenue generated per day from the project by the duration of the hazard and the percentage of the asset impacted (Eqn. 3).

Revenue Loss = Revenue generated (per day)*Duration of hazard*% of asset impacted	**Eqn. 3**

Cost of resilience

The cost of resilience is calculated by multiplying the unit cost of the resilience measure by the measurement of the asset to be treated (Eqn. 4).

Cost of Resilience=Unit cost of resilience mesaure*Measurement of asset to be treated	**Eqn. 4**

Benefit

The benefit or saving is calculated by multiplying the sum of recovery needs over the project life cycle and revenue loss by the percentage of resilience achieved (Eqn. 5).

Saving=(Recovery needs over the life cycle+Revenue loss)*% of resilience achieved	**Eqn. 5**

The outputs of the cost-benefit analysis shown in Figure 7.2 represent the benefits increase for high-return period hazards and vice versa. The benefit may also change for different geographical regions for similar infrastructure types.

The analysis has the following limitations as it is confined within measurable parameters to have a quantitative assessment. A few of these are listed below:

i. **Limited assessment of resilience benefit:** Natural hazards incur both direct and indirect losses. The direct losses include the direct damage to the assets, and indirect losses include all cascading impacts such as social, environmental, and economic impacts, caused by the hazard. This analysis only considers the direct losses and corresponding benefits.

ii. **Uncertainty in data and assessment:** The CBA approach considers the threshold approach and is dependent on data which has limited accuracy due to limitations in predicting hazard parameters.

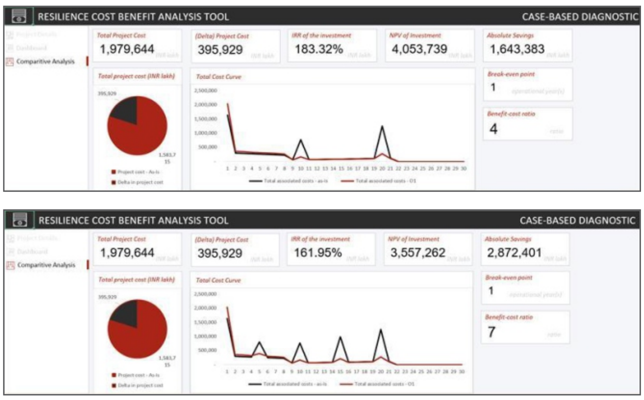


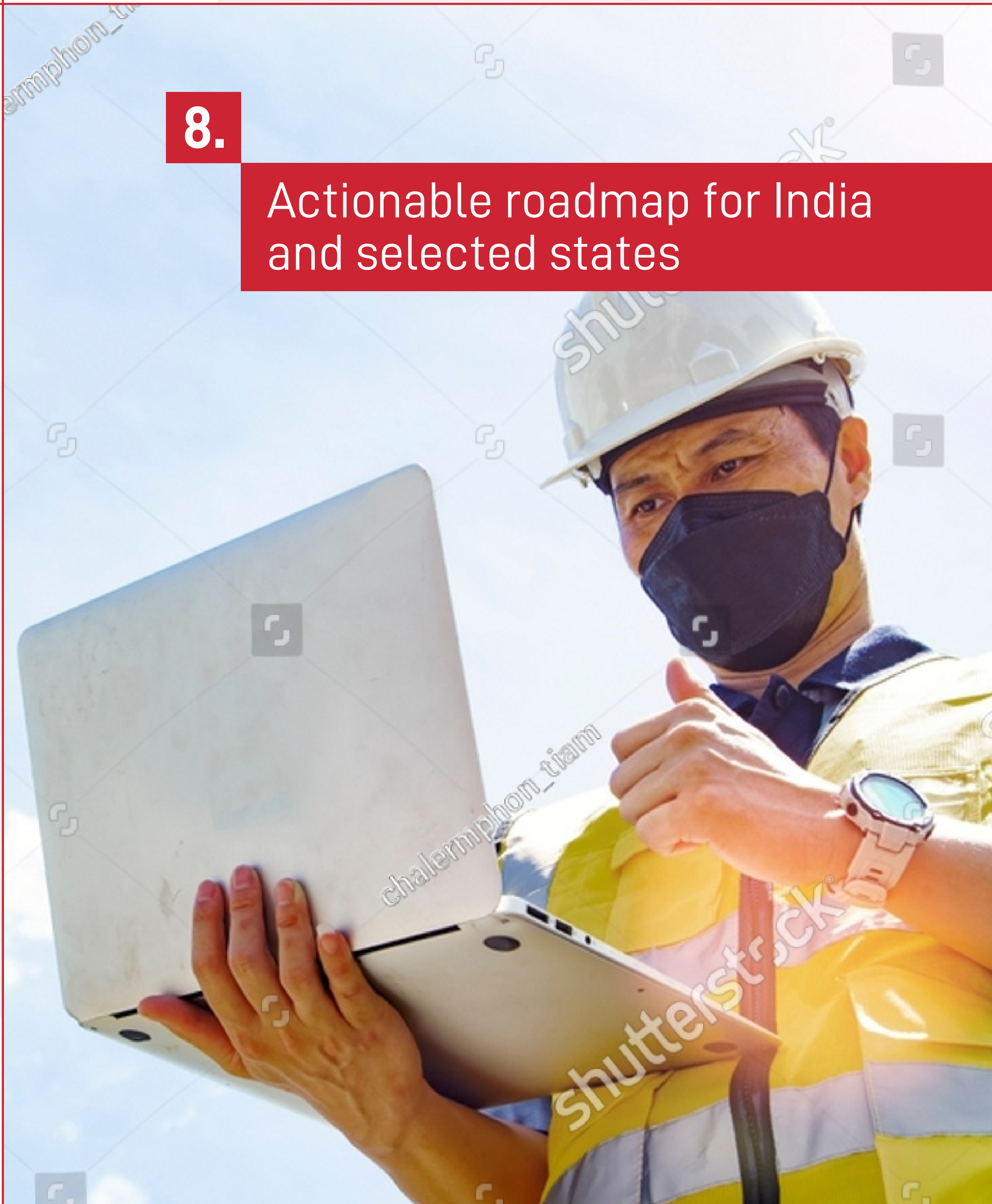
Figure 7.2: Outputs of CBA

iii. **Average cost of estimation:** Estimating the costs of resilient infrastructure is geography dependent. This assessment does not consider the variation in cost of materials, construction practices, and labor costs across different regions.

iv. **Non-consideration of dynamic risk profile:** Climate change and evolving socio-economic conditions can alter risk profiles and infrastructure needs, potentially making assessment less accurate over a spatio-temporal scale.

v. **Limited consideration of interdependencies:** The assessment has only considered the limited aspects of power sector interdependence.

8. Actionable roadmap for India and selected states



8.1. Actionable roadmap for India

1 year | 1-3 years | >3 years

Table 8.1: Actionable roadmap: India

<table>
<tr><th rowspan="2">Stakeholders</th><th colspan="3">Actionable roadmap</th></tr>
<tr><th>Pre-disaster</th><th>During disaster</th><th>Post-disaster</th></tr>
<tr><td rowspan="10">DoT/LSA</td><td>Update the data format for a comprehensive assessment of disaster impacts on assets</td><td>Provision for single window permission system to expedite restoration work</td><td>Establish a digital knowledge platform to share disaster learnings across different LSAs</td></tr>
<tr><td>Disaster preparedness and planning should be carried out using local-scale catastrophic risk model outputs.</td><td rowspan="4">MTTR (mean time to repair) and fault incidence should be accounted weekly to comprehensively assess the resilience of these infrastructure system</td><td>A disaster task force to be constituted at the LSA level to validate asset damage loss information received from operators</td></tr>
<tr><td>Develop a protocol for seamless connectivity across different telecommunications devices for disaster communication purposes</td><td>Mainstream disaster risk and impact data collection for all hazards across the country</td></tr>
<tr><td>Plan and expand domestic sub-marine cable across coastal cities having low disaster vulnerability profile</td><td rowspan="3">Carry out comprehensive resource need assessment for preventive maintenance and restoration work every 25-50 km (15.5- 31.06 miles) for effective disaster management.</td></tr>
<tr><td>Provision for multiple cable landing zones across coastal states to ensure sufficient redundancy</td></tr>
<tr><td>DoT should consult line ministries and develop a comprehensive guideline for using the street furniture to mitigate damage/impact of this furniture</td><td rowspan="5">Cell bouncing busy hour assessment should be carried out at district/sub-district scale for each disaster event to understand the telecommunications peak traffic duration profile across different geographies for multiple disaster scenarios</td></tr>
<tr><td>Develop a telecommunications infrastructure resilience index for each LSA</td><td rowspan="2">The number of call attempts made by users should be audited for golden hours after every disaster event to comprehensively assess the connectivity</td></tr>
<tr><td>Extend inter-band spectrum sharing for disaster communication purposes</td></tr>
<tr><td>Provision of specialized Indian shipping vessels for repair of the submarine cables to expedite the restoration activities</td><td rowspan="2">DCR assessment methodology should consider district/sub-district scale analysis of the impacted region rather than LSA scale analysis</td></tr>
<tr><td>Extend financial support through USOF/Digital Bharat Nidhi to establish SESG for providing connectivity to the mountainous regions through the LEO satellite constellation in the future</td></tr>
</table>

Stakeholders	Actionable roadmap		
	Pre-disaster	**During disaster**	**Post-disaster**
	Provision for the availability of user-friendly satellite phones for disaster communication purposes		
	Carry out country-wide GIS-based OFC cable network mapping for planning and management of the OFC cable across the country		
	DoT may issue policy guidelines to all state government departments and central ministries to provide adequate emergency communication devices for disaster needs, which state government and line departments may follow		
	Provide funding support to operators for setting up an asset in the non-feasible regions through the bidding or nomination process, which will be under the control of the DoT. Other operators may latch based on the tariffs defined by TRAI. Additional spectrum may be allocated during emergency situations.		
	Form a team that will work in close collaboration with SDMA for new initiatives and faster response during emergency		
	Maintain an appropriate number of CoWs centrally and may deploy it as per the requirements across the country		
ASDMA/DDMA	Develop comprehensive guidelines for prioritizing fuel supply for the impacted region	DDMA should share the telecommunications network restoration update to the last-mile consumer through daily bulletin	
	Priority support and arrangement of fuel, power and transportation by district administration		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	SDMA should provision the financial arrangement/incentive for compensating telecommunications infrastructure damage/ losses resulting from disasters	-	
	SDMA should carry out a comprehensive assessment for minimum telecommunications service connectivity required across disaster-vulnerable regions and identify critical infrastructure providing the telecommunications services		
	Develop a GIS-based hazard zonation map at district/sub-district scale		
	SDMA should develop a guideline to establish a telecommunications network across disaster shelters		
	SDMA should develop guidelines to ensure priority service restoration and critical connectivity during disaster through Service-Level Agreements between industrial bodies and operators		
	SDMA should provision to connect each 'Aapda Mitra' volunteer with alternate communication technologies such as short-wave radio communication		
State Line Department	Make provisions for common ducts along the road network for operators based on a cost-sharing mechanism		
Power	Ensure power supply to critical telecommunications sites through captive power arrangement or through microgrid		

Stakeholders	Actionable roadmap		
	Pre-disaster	**During disaster**	**Post-disaster**
	Provision connecting each DC with a minimum of two different feeder lines existing in different hazard-vulnerable zones		
Road	Promote wider usage of the Call Before you Dig (CBuD) App across the country		
Building	Carry out multi-hazard building vulnerability assessment before approving Roof Top Towers (RTT) installation on buildings		
	Ensure building codes are strictly followed based on the geographical hazard vulnerability profile		
Operators	Carry out a comprehensive assessment for pre-positioning of temporary telecommunications network and deployment Cell on Balloon, Cell on Truck, Cell on Ship and Boat	Provision for High Altitude Platform System (HAPS) to establish an emergency communication network using solar power drones at an altitude between 18-25 km (11.1 - 15.5 miles) to provide emergency communication coverage up to 200 km (124.2 miles) area	Follow guidelines and ensure quality restoration in the post-disaster phase
	Restore landline phones across disaster-vulnerable regions to ensure better redundancy	-	
	Carry out local scale hazard risk assessment to understand the impact of the disaster on telecommunications infrastructure system, raising generator height, re-establish optical fibre using elastic optical network technologies, provision for battery backup and strengthen tower/antenna design to withstand probable maximum hazard impact across the region		Carry out comprehensive assessments of call traffic surge at sub-district scale for each disaster event and plan network capacity expansion in the future
	Equip the sites with flood doors and waterproof cable connections		

8.2. Assam

1 year | 1-3 years | >3 years

Table 8.2: Actionable roadmap: Assam

Stakeholders	Actionable roadmap		
	Pre-disaster	**During disaster**	**Post-disaster**
Assam-LSA	Update the data format for a comprehensive assessment of disaster impacts on assets	Provision for single window permission system to expedite restoration work	A disaster task force at Assam-LSA needs to be constituted at Assam-LSA level for validating asset damage loss information received from operators
	Disaster preparedness and planning should be carried out using local-scale catastrophic risk model outputs		Mainstream disaster risk and impact data collection for all hazards across the state
	Develop a protocol for seamless connectivity across different telecommunication devices for disaster communication purposes		Carry out comprehensive resource need assessment for preventive maintenance and restoration work every 25-50 km (15.5- 31.06 miles) for effective disaster management
	Provision for multiple cable landing zones across coastal states to ensure sufficient redundancy	MTTR (mean time to repair) and fault incidence should be accounted for weekly to comprehensively assess the resilience of these infrastructure systems	The number of call attempts made by users should be audited for golden hours after every disaster event to comprehensively assess the connectivity
	Consult Line Ministries and develop a comprehensive guideline for using the street furniture to mitigate damage/impact of this furniture		
	Develop telecommunication infrastructure resilience index for Assam-LSA		
	Extend financial support through USOF/Digital Bharat Nidhi to establish SESG for providing connectivity to the mountainous regions through the LEO satellite constellation in the future	Cell bouncing busy hour assessment should be carried out at the district/sub-district scale for each disaster event to understand the telecommunications peak traffic duration profile across different geographies for multiple disaster scenarios	DCR assessment methodology should consider district/sub-district scale analysis of the impacted region rather than Assam-LSA scale analysis
	Provision for the availability of user-friendly satellite phones for disaster communication purposes		
	Assam-LSA should carry out country-wide GIS-based OFC cable network mapping for planning and management of the OFC cable across the state		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Provide funding support to operators for setting up an asset in the non-feasible regions through the bidding or nomination process, which will be under the control of Assam LSA. Other operators may latch based on the tariffs defined by TRAI. Additional spectrum may be allocated during emergency situations		
	Form a team that will work in close collaboration with SDMA for new initiatives and faster response during emergency		
	Maintain an appropriate number of CoWs and may deploy it as per the requirements across the state		
ASDMA/DDMA	Develop comprehensive guidelines for prioritizing fuel supply and its strategic storage across the vulnerable region Priority support and arrangement of fuel, power and transportation by district administration	DDMA should share the telecommunications network restoration update to the last-mile consumer through daily bulletin	-
	ASDMA should provision the financial arrangement / incentive for compensating telecommunications infrastructure damage / losses resulting from disaster	-	
	ASDMA should carry out a comprehensive assessment for minimum telecommunications service connectivity required across disaster-vulnerable regions and identify critical infrastructure providing the telecommunication services		
	Develop a GIS-based hazard zonation map at district/sub-district scale		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	ASDMA should prepare a revised wind and flood hazard zonation map	-	-
	ASDMA should develop a guideline to establish a telecommunications network across disaster shelters		
	ASDMA should develop guidelines to ensure priority service restoration and critical connectivity during disaster through Service-Level Agreements between industrial bodies and operators		
	ASDMA should provision to connect each 'Aapda Mitra' volunteer/Gaon Burha (Village Heads) with alternate communication technologies such as short-wave radio communication		
State line departments	Provide a dedicated annual departmental budget for strengthening the disaster resilience of infrastructure by assessing the historical damage/loss information		
	Make provisions for common ducts along the road network for operators based on cost sharing mechanism		
Power	Ensure power supply to critical telecommunications sites through captive power arrangement or microgrid		
	Provision connecting each DC with a minimum of two different feeder lines existing in different hazard-vulnerable zones		
Road	Promote wider usage of Call Before you Dig (CBuD) App across the country		
Building	Carry out multi-hazard building vulnerability assessment before approving Roof Top Towers (RTT) installation on buildings		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Ensure building codes are strictly followed based on the earthquake vulnerability profile		
Operators	Carry out comprehensive assessment for pre-positioning of temporary telecommunications network and deployment Cell on Balloon, Cell on Truck, Cell on Boat	Provision for High Altitude Platform System (HAPS) to establish an emergency communication network using solar power drones at an altitude between 18-25 km (11.1 - 15.5 miles) to provide emergency communication coverage up to 200 km (124.2 miles) area	Follow guidelines and ensure quality restoration in the post-disaster phase
	Restore landline phones across disaster-vulnerable regions to ensure better redundancy	-	Carry out comprehensive assessments of call traffic surge at sub-district scale for each disaster event and plan network capacity expansion in the future
	The operator should increase the GBT tower foundation from 10 m to 15 m across highly vulnerable slopes		
	Monitor the vibration/deformation in OFC cable network using a Coherent OTDR (Optical Time Domain Reflectometer)		
	Carry out local scale hazard risk assessment to understand the impact of disaster on telecommunications infrastructure system, raising generator height, re-establish optical fibre using elastic optical network technologies, provision for battery backup and strengthen tower/antenna design to withstand probable maximum hazard impact across the region		-
	Equip the sites with flood doors and waterproof cable connections		

8.3. Odisha

1 year | 1-3 years | >3 years

Table 8.3: Actionable roadmap: Odisha

<table>
<tr><th rowspan="2">Stakeholders</th><th colspan="3">Actionable roadmap</th></tr>
<tr><th>Pre-disaster</th><th>During disaster</th><th>Post-disaster</th></tr>
<tr><td rowspan="10">Odisha-LSA</td><td>Update the data format for a comprehensive assessment of disaster impacts on assets</td><td rowspan="3">Provision for a single window permission system to expedite restoration work</td><td>A disaster task force at Gujarat-LSA needs to be constituted at the Gujarat-LSA level to validate asset damage loss information received from operators</td></tr>
<tr><td>Disaster preparedness and planning should be carried out using local-scale catastrophic risk model outputs</td><td>Mainstream disaster risk and impact data collection for all hazards across the state</td></tr>
<tr><td>Prepare a guideline for operators that critical telecommunications tower should withstand the basic wind speed of up to 250 km/h and antenna should withstand the wind speed of 150 km/h across the coastal region (10 km from the coastline)</td><td rowspan="3">Carry out comprehensive resource need assessment for preventive maintenance and restoration work every 25-50 km (15.5- 31.06 miles) for effective disaster management</td></tr>
<tr><td>Develop a protocol for seamless connectivity across different telecommunications devices for disaster communication purposes</td><td rowspan="3">MTTR (mean time to repair) and fault incidence should be accounted for weekly to comprehensively assess the resilience of these infrastructure systems</td></tr>
<tr><td>Plan and expand domestic sub-marine cable across coastal cities having low disaster vulnerability profile</td></tr>
<tr><td>Provision for multiple cable landing zones across coastal states to ensure sufficient redundancy</td><td rowspan="3">The number of call attempts made by users should be audited for golden hours after every disaster event to comprehensively assess the connectivity</td></tr>
<tr><td>Consult line ministries and develop a comprehensive guideline for using the street furniture to mitigate damage/impact of this furniture</td><td rowspan="4">Cell bouncing busy hour assessment should be carried out at the district/sub-district scale for each disaster event to understand the telecommunications peak traffic duration profile across different geographies for multiple disaster scenarios</td></tr>
<tr><td>Develop telecommunications infrastructure resilience index for Odisha-LSA</td></tr>
<tr><td>Extend inter-band spectrum sharing for disaster communication purposes</td><td>DCR assessment methodology should consider district/sub-district scale analysis of the impacted region rather than</td></tr>
</table>

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Provision for the availability of user-friendly satellite phones for disaster communication purposes		Odisha-LSA scale analysis
	Carry out country-wide GIS-based OFC cable network mapping for planning and management of the OFC cable across the state		
	Provide funding support to operators for setting up an asset in the non-feasible regions through the bidding or nomination process, which will be under the control of Odisha LSA. Other operators may latch based on the tariffs defined by TRAI. Additional spectrum may be allocated during emergencies		
	Form a team that will work in close collaboration with SDMA for new initiatives and faster response during emergency		
	Maintain an appropriate number of CoWs and may deploy them as per the requirements across the state		
OSDMA/DDMA	Develop comprehensive guidelines for prioritizing fuel supply for the impacted region	DDMA should share the telecommunications network restoration update to the last-mile consumer through daily bulletin	-
	Priority support and arrangement of fuel, power, and transportation by district administration		
	OSDMA should provision the financial arrangement/incentive for compensating telecommunications infrastructure damage/losses resulting from disaster	-	

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	OSDMA should carry out a comprehensive assessment for minimum telecommunications service connectivity required across disaster-vulnerable regions and identify critical infrastructure providing the telecommunications services	-	-
	Develop a GIS-based hazard zonation map at district/sub-district scale		
	OSDMA should prepare a revised wind and flood hazard zonation map		
	OSDMA should develop a guideline to establish a telecommunications network across disaster shelters		
	OSDMA should develop guidelines to ensure priority service restoration and critical connectivity during disaster through Service-Level Agreements between industrial bodies and operators		
	OSDMA should provision to connect each 'Aapda Mitra' volunteer with alternate communication technologies such as short-wave radio communication		
State Line Department	Provide a dedicated annual departmental budget for strengthening the disaster resilience of infrastructure by assessing the historical damage/loss information		
Power	Make provisions for common ducts along the road network for operators based on cost sharing mechanism		
	Ensure power supply to critical telecommunications sites through captive power arrangement or microgrid		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Provision connecting each DC with a minimum of two different feeder lines existing in different hazard-vulnerable zones		
Road	Promote wider usage of the Call Before you Dig (CBuD) App across the country		
Building	Carry out multi-hazard building vulnerability assessment before approving Roof Top Towers (RTT) installation on buildings		
	Ensure building codes are strictly followed based on the geographical hazard vulnerability profile		
Operators	Carry out a comprehensive assessment for pre-positioning of temporary telecommunications network and deployment Cell on Balloon, Cell on Truck, Cell on Ship and Boat	Provision for High Altitude Platform System (HAPS) to establish an emergency communication network using solar power drones at an altitude between 18-25 km (11.1 - 15.5 miles) to provide emergency communication coverage up to 200 km (124.2 miles) area	Follow guidelines and ensure quality restoration in the post-disaster phase
	Restore landline phones across disaster-vulnerable regions to ensure better redundancy		Carry out comprehensive assessments of call traffic surge at sub-district scale for each disaster event and plan network capacity expansion in the future
	Raise generator heights in the regions (up to 5 km (3. 1 miles) inside the coast) to withstand the impact of storm surge flooding	-	-
	Plan for fire-resistant optical fibre network and other telecommunications infrastructure in highly sensitive forest fire zone		
	Carry out local scale hazard risk assessment to understand the impact of the disaster on the telecommunications infrastructure system, re-establish optical fibre using elastic optical network technologies, provision for battery backup and strengthen tower/antenna design to withstand probable maximum hazard impact across the region		
	Equip the sites with flood doors and waterproof cable connections		

8.4. Uttarakhand

1 year 1-3 years >3 years

Table 8.4: Actionable roadmap: Uttarakhand

Stakeholders	Actionable roadmap		
	Pre-disaster	**During disaster**	**Post-disaster**
Uttarakhand-LSA	UP West-LSA should update the data format for a comprehensive assessment of disaster impacts on assets	Provision for a single window permission system to expedite restoration work	Establish a digital knowledge platform to share disaster learnings across different UP West-LSA for validating asset damage loss information received from operators
	Disaster preparedness and planning should be carried out using local-scale catastrophic risk model outputs		A disaster task force at UP West-LSA needs to be constituted at UP West-LSA level
	Develop a protocol for seamless connectivity across different telecommunications devices for disaster communication purpose	MTTR (mean time to repair) and fault incidence should be accounted for weekly to comprehensively assess the resilience of these infrastructure systems	Mainstream disaster risk and impact data collection for all hazards across the state
	UP West-LSA should consult line ministries and develop a comprehensive guideline for using the street furniture to mitigate damage/impact of this furniture		Carry out comprehensive resource need assessment for preventive maintenance and restoration work every 25-50 km (15.5- 31.06 miles) for effective disaster management
	Develop telecommunications infrastructure resilience index for UP West-LSA		The number of call attempts made by users should be audited for golden hours after every disaster event to comprehensively assess the connectivity
	Extend inter-band spectrum sharing for disaster communication purposes	Cell bouncing busy hour assessment should be carried out at the district/sub-district scale for each disaster event to understand the telecommunications peak traffic duration profile across different geographies for multiple disaster scenarios	DCR assessment methodology should consider district/sub-district scale analysis of the impacted region rather than UP West-LSA scale analysis
	Extend financial support through USOF/Digital Bharat Nidhi to establish SESG for providing connectivity to the mountainous regions through the LEO satellite constellation in the future		
	Provision for the availability of user-friendly satellite phones for disaster communication purposes		
	UP West-LSA should carry out country-wide GIS-based OFC cable network mapping for planning and management of the OFC cable across the state		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Provide funding support to operators for setting up an asset in the non-feasible regions through the bidding or nomination process, which will be under the control of UP-West LSA. Other operators may latch based on the tariffs defined by TRAI. Additional spectrum may be allocated during emergencies		
	Form a team that will work in close collaboration with SDMA for new initiatives and faster response during emergency		
	Maintain an appropriate number of CoWs and may deploy it as per the requirements across the state		
UKSDMA/DDMA	Develop comprehensive guidelines for prioritizing fuel supply and its strategic storage across the vulnerable region	DDMA should share the telecommunications network restoration update to the last-mile consumer through daily bulletin	-
	Priority support and arrangement of fuel, power, and transportation by district administration		
	USDMA should provision the financial arrangement/ incentive for compensating telecommunications infrastructure damage/losses resulting from disasters	-	
	USDMA should carry out a comprehensive assessment for minimum telecommunications service connectivity required across disaster-vulnerable regions and identify critical infrastructure providing the telecommunications services		
	Develop a GIS-based hazard zonation map at district/sub-district scale		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	USDMA should develop a guideline to establish a telecommunications network across disaster shelters		
	USDMA should develop guidelines to ensure priority service restoration and critical connectivity during disaster through Service-Level Agreements between industrial bodies and operators		
	USDMA should provision to connect each 'Aapda Mitra' volunteer with alternate communication technologies such as short-wave radio communication and leverage Radio Kedar for emergency communication purposes		
State Line Department	Provide a dedicated annual departmental budget for strengthening the disaster resilience of infrastructure by assessing the historical damage/loss information		
	Make provisions for common ducts along the road network for operators based on cost sharing mechanism		
Power	Ensure power supply to critical telecommunications sites through captive power arrangement or microgrid		
	Provision connecting each DC with a minimum of two different feeder lines existing in different hazard-vulnerable zones		
Road	Promote wider usage of Call Before you Dig (CBuD) App across the country		
Building	Carry out multi-hazard building vulnerability assessment before approving Roof Top Towers (RTT) installation on buildings		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Ensure building codes are strictly followed based on the earthquake vulnerability profile		
Operators	Carry out comprehensive assessment for pre-positioning of temporary telecommunication network, and deployment Cell on Balloon, Cell on Truck, Cell on Boat	Provision for High Altitude Platform System (HAPS) to establish an emergency communication network using solar power drones at an altitude between 18-25 km (11.1 - 15.5 miles) to provide emergency communication coverage up to 200 km (124.2 miles) area	Follow guidelines and ensure quality restoration in post-disaster phase
	Restore landline phones across disaster-vulnerable regions to ensure better redundancy		
	The operator should increase the GBT tower foundation from 10m to 15m across high, vulnerable slopes		
	Plan for fire-resistant optical fibre network and other telecommunications infrastructure in highly sensitive forest fire zone		
	Monitor the vibration/deformation in OFC cable network using a Coherent OTDR (Optical Time Domain Reflectometer)		Carry out comprehensive assessments of call traffic surge at sub-district scale for each disaster event and plan network capacity expansion in the future
	Carry out local scale hazard risk assessment to understand the impact of disaster on telecommunications infrastructure system, raising generator height, re-establish optical fibre using elastic optical network technologies, provision for battery backup, and strengthen tower/antenna design to withstand probable maximum hazard impact across the region		

8.5. Tamil Nadu

1 year | 1-3 years | >3 years

Table 8.5: Actionable roadmap: Tamil Nadu

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
Tamil Nadu-LSA	Tamil Nadu-LSA should update the data format for a comprehensive assessment of disaster impacts on assets	Provision for a single window permission system to expedite restoration work	A disaster task force at Tamil Nadu-LSA needs to be constituted at Tamil Nadu-LSA level for validating asset damage loss information received from operators
	Disaster preparedness and planning should be carried out using local-scale catastrophic risk model outputs		
	Prepare a guideline for operators that critical telecommunication tower should withstand the basic wind speed of up to 250 km/h (155.3 miles/h) and that the antenna should withstand the wind speed of 150 km/h (93.2 miles/h) across the coastal region (10 km (6.21 miles) from the coastline)		
	Develop a protocol for seamless connectivity across different telecommunications devices for disaster communication purposes	MTTR (mean time to repair) and fault incidence should be accounted for weekly to comprehensively assess the resilience of these infrastructure system	Mainstream disaster risk and impact data collection for all hazards across the state
	Plan and expand domestic sub-marine cable across coastal cities having low disaster vulnerability profile		Carry out comprehensive resource need assessment for preventive maintenance and restoration work every 25-50 km for effective disaster management
	Provision for multiple cable landing zones across coastal states to ensure sufficient redundancy	Cell bouncing busy hour assessment should be carried out at the district/sub-district scale for each disaster event to understand the telecommunications peak traffic duration profile across different geographies for multiple disaster scenarios	The number of call attempts made by users should be audited for golden hours after every disaster event to comprehensively assess the connectivity
	Consult Line Ministries and develop a comprehensive guideline for using the street furniture to mitigate damage/impact of this furniture		
	Develop telecommunications infrastructure resilience index for Tamil Nadu-LSA		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Extend inter-band spectrum sharing for disaster communication purposes		DCR assessment methodology should consider district/sub-district scale analysis of the impacted region rather than Tamil Nadu-LSA scale analysis
	Provision of specialized Indian shipping vessels for repair of the submarine cables to expedite the restoration activities		
	Provision for the availability of user-friendly satellite phones for disaster communication purposes		
	Tamil Nadu-LSA should carry out country-wide GIS-based OFC cable network mapping for planning and management of the OFC cable across the state		
	Provide funding support to operators for setting up an asset in the non-feasible regions through the bidding or nomination process, which will be under the control of Tamil Nadu LSA based on the tariffs defined by TRAI. Additional spectrum may be allocated during emergencies		
	Form a team that will work in close collaboration with SDMA for new initiatives and faster response during emergency		
	Maintain an appropriate number of CoWs and may deploy it as per the requirements across the state		
TNSDMA/DDMA	Develop comprehensive guidelines for prioritizing fuel supply for the impacted region	Develop comprehensive guidelines on sustainable waste management of telecommunications waste under state e-waste policy	-
	Priority support and arrangement of fuel, power and transportation by district administration		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	TNSDMA should provision the financial arrangement/incentive for compensating telecommunications infrastructure damage/losses resulting from disasters		
	TNSDMA should carry out a comprehensive assessment for minimum telecommunications service connectivity required across disaster-vulnerable region and identify critical infrastructure providing the telecommunications services		
	Develop a GIS-based hazard zonation map at the district/sub-district scale		
	TNSDMA should prepare a revised wind and flood hazard zonation map		
	TNSDMA should develop a guideline to establish a telecommunications network across disaster shelters		
	TNSDMA should develop guidelines to ensure priority service restoration and critical connectivity during disaster through Service-Level Agreements between industrial bodies and operators		
	TNSDMA should provision to connect each 'Aapda Mitra' volunteer with alternate communication technologies such as short-wave radio communication		
State Line Department	Provide a dedicated annual departmental budget for strengthening the disaster resilience of infrastructure by assessing the historical damage/loss information	-	-

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Make provisions for common ducts along the road network for operators based on cost sharing mechanism		
Power	Ensure power supply to critical telecommunications sites through captive power arrangement or microgrid		
	Provision connecting each DC with a minimum of two different feeder lines existing in different hazard-vulnerable zones		
Road	Promote wider usage of the Call Before you Dig (CBuD) App across the country		
Building	Carry out multi-hazard building vulnerability assessment before approving Roof Top Towers (RTT) installation on buildings		
	Ensure building codes are strictly followed based on the geographical hazard vulnerability profile		
Operators	Carry out a comprehensive assessment for pre-positioning of temporary telecommunications network and deployment Cell on Balloon, Cell on Truck, Cell on Ship and Boat	Provision for High Altitude Platform System (HAPS) to establish an emergency communication network using solar power drones at an altitude between 18-25 km (11.1 - 15.5 miles) to provide emergency communication coverage up to 200 km (124.2 miles) area	Follow guidelines and ensure quality restoration in the post-disaster phase
	Restore landline phones across disaster-vulnerable regions to ensure better redundancy		
	Raise generator heights in the regions (up to 5 km (3.1 miles) inside the coast) to withstand the impact of storm surge flooding		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Monitor the vibration/deformation in OFC cable network using a Coherent OTDR (Optical Time Domain Reflectometer)		Carry out comprehensive assessments of call traffic surge at sub-district scale for each disaster event and plan network capacity expansion in future
	Carry out local scale hazard risk assessment to understand the impact of disaster on telecommunications infrastructure system, re-establish optical fibre using elastic optical network technologies, provision for battery backup and strengthen tower/antenna design to withstand probable maximum hazard impact across the region		
	Equip the sites with flood doors and waterproof cable connections		

8.6. Gujarat

1 year | 1-3 years | >3 years

Table 8.6: Actionable roadmap: Gujarat

<table>
<tr><th rowspan="2">Stakeholders</th><th colspan="3">Actionable roadmap</th></tr>
<tr><th>Pre-disaster</th><th>During disaster</th><th>Post-disaster</th></tr>
<tr><td rowspan="8">Gujarat-LSA</td><td>Update the data format for a comprehensive assessment of disaster impacts on assets</td><td rowspan="2">Provision for a single window permission system to expedite restoration work</td><td rowspan="2">A disaster task force at Gujarat-LSA needs to be constituted at the Gujarat-LSA level to validate asset damage loss information received from operators</td></tr>
<tr><td>Disaster preparedness and planning should be carried out using local-scale catastrophic risk model outputs</td></tr>
<tr><td>Prepare a guideline for operators that critical telecommunication tower should withstand the basic wind speed of up to 200 km/h (124.2 miles/h) and that the antenna should withstand the wind speed of 150 km/h (93.2 miles/h) across the coastal region (10 km (6.21 miles) from the coastline)</td><td rowspan="2">MTTR (mean time to repair) and fault incidence should be accounted for weekly to comprehensively assess the resilience of these infrastructure systems</td><td rowspan="2">Mainstream disaster risk and impact data collection for all hazards across the state</td></tr>
<tr><td>Develop a protocol for seamless connectivity across different telecommunications devices for disaster communication purposes</td></tr>
<tr><td>Plan and expand domestic sub-marine cables across coastal cities having low disaster vulnerability profile</td><td></td><td>Carry out comprehensive resource need assessment for preventive maintenance and restoration work every 25-50 km (15.5- 31.06 miles) for effective disaster management</td></tr>
<tr><td>Provision for multiple cable landing zones across coastal states to ensure sufficient redundancy</td><td rowspan="3">Cell bouncing busy hour assessment should be carried out at the district/sub-district scale for each disaster event to understand the telecommunications peak traffic duration profile across different geographies for multiple disaster scenarios</td><td rowspan="3">The number of call attempts made by users should be audited for golden hours after every disaster event to comprehensively assess the connectivity</td></tr>
<tr><td>Consult Line Ministries and develop a comprehensive guideline for using the street furniture to mitigate damage/impact of this furniture</td></tr>
<tr><td>Develop telecommunications infrastructure resilience index for Gujarat-LSA</td></tr>
</table>

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Extend inter-band spectrum sharing for disaster communication purposes		DCR assessment methodology should consider district/sub-district scale analysis of the impacted region rather than Gujarat-LSA scale analysis
	Provision for the availability of user-friendly satellite phones for disaster communication purposes		
	Carry out country-wide GIS-based OFC cable network mapping for planning and management of the OFC cable across the state		
	Provide funding support to operators for setting up an asset in the non-feasible regions through the bidding or nomination process, which will be under the control of Gujarat LSA based on the tariffs defined by TRAI. Additional spectrum may be allocated during emergency situations		
	Form a team that will work in close collaboration with SDMA for new initiatives and faster response during emergency		
	Maintain an appropriate number of CoWs and may deploy it as per the requirements across the state		
GSDMA/DDMA	Develop comprehensive guidelines for prioritizing fuel supply for the impacted region	DDMA should share the telecommunications network restoration update to the last-mile consumer through daily bulletins	-
	Priority support and arrangement of fuel, power and transportation by district administration	-	
	GSDMA should provision the financial arrangement/ incentive for compensating telecommunications infrastructure damage/ losses resulting from disasters		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	GSDMA should carry out a comprehensive assessment for minimum telecommunications service connectivity required across disaster-vulnerable regions and identify critical infrastructure providing the telecommunications services		-
	Develop a GIS-based hazard zonation map at district/sub-district scale		
	GSDMA should prepare a revised wind and flood hazard zonation map		
	GSDMA should develop a guideline to establish a telecommunications network across disaster shelters		
	GSDMA should develop guidelines to ensure priority service restoration and critical connectivity during disaster through Service-Level Agreements between industrial bodies and operators		
	GSDMA should provision to connect each 'Aapda Mitra' volunteer with alternate communication technologies such as short-wave radio communication		
State Line Department	Provide a dedicated annual departmental budget for strengthening the disaster resilience of infrastructure by assessing the historical damage/loss information	-	-
	Make provisions for common ducts along the road network for operators based on cost-sharing mechanism		
Power	Ensure power supply to critical telecommunications sites through captive power arrangement or microgrid	-	-
	Provision of power supply to rural telecommunications assets through dedicated agri-feeder		

Stakeholders	Actionable roadmap		
	Pre-disaster	During disaster	Post-disaster
	Provision connecting each DC with a minimum of two different feeder lines existing in different hazard-vulnerable zones		
Road	Promote wider usage of Call Before you Dig (CBuD) App across the country		
Building	Carry out multi-hazard building vulnerability assessment before approving Roof Top Towers (RTT) installation on buildings		
	Ensure building codes are strictly followed based on the earthquake-vulnerability profile		
Operators	Carry out a comprehensive assessment for pre-positioning of temporary telecommunications network and deployment Cell on Balloon, Cell on Truck, Cell on Ship and Boat	Provision for High Altitude Platform System (HAPS) to establish an emergency communication network using solar power drones at an altitude between 18-25 km (11.1 - 15.5 miles) to provide emergency communication coverage up to 200 km (124.2 miles) area	Follow guidelines and ensure quality restoration in the post-disaster phase
	Restore landline phones across disaster-vulnerable regions to ensure better redundancy		
	Raise generator heights in the regions (up to 5 km (3.1 miles) inside the coast) to withstand the impact of storm surge flooding	-	
	Monitor the vibration/deformation in the OFC cable network using a Coherent OTDR (Optical Time Domain Reflectometer)		Carry out comprehensive assessments of call traffic surge at sub-district scale for each disaster event and plan network capacity expansion in future
	Carry out local scale hazard risk assessment to understand the impact of disaster on telecommunications infrastructure system, re-establish optical fibre using elastic optical network technologies, provision for battery backup and strengthen tower/antenna design to withstand probable maximum hazard impact across the region		
	Equip the sites with flood doors and waterproof cable connections		

9. Annexures

Annexure 1: Classification of PPDR application

Table A.1: Classification of PPDR application

Application	Feature	PPDR example
1. Narrowband		
Voice	Person-to-person	Selective calling and addressing
	One-to-many	Dispatch and group communication
	Talk-around/direct mode operation	Groups of portable-to-portable (mobile-mobile) in close proximity without infrastructure
	Push-to-talk	Push-to-talk
	Installation access to the voice path	Push-to-talk and selective priority access
	Security	Voice
Facsimile	Person-to-person	Status, short message
	One-to-many (broadcasting)	Initial dispatch alert (e.g., address, incident status)
Messages	Person-to-person	Status, short messages, short e-mail
	One-to-many (broadcasting)	Initial dispatch alert (e.g., address, incident status)
Security	Priority/instantaneous access	Man, down alarm button
Telemetry	Location status	GPS latitude and longitude information
	Sensory data	Vehicle telemetry/status
		EKG (electrocardiograph) in field
Database interaction (minimal record size)	Forms based records query	Accessing vehicle license records
	Forms based on incident report	Filing field report
2. Wideband		
Messages	Emails, possibly with attachments	Routine email messages
Data talk around/direct mode operation	Direct unit to unit	Direct handset-to-handset, on-scene localized communication
	Communication without additional infrastructure	
Database interaction (medium record size)	Forms and record query	Accessing medical records
		Lists of identified person/missing
		Person
		GIS (Geographical Information Systems)

Application	Feature	PPDR example
Text file Transfer	Data transfer	Filling report from the scene of incident
		Records management system information on offenders
		Downloading legislative information
Image transfer	Download/upload of compressed still images	Biometrics (fingerprints)
		ID picture
		Building layout maps
Telemetry	Location status and sensory data	Vehicle status
Security	Priority access	Critical care
Video	Download/upload compressed video	Video clips
		Patient monitoring (may require a dedicated link)
		Video feed of the in-progress incident
Interactive	Location determination	2-way system
		Interactive location data
3. Broadband		
Database access	Intranet/internet access	Accessing architectural plans of buildings, location of hazardous materials
	Web browsing	Browsing the directory of PPDR organization for phone number
Robotics control	Remote control of robotic device	Bomb retrieval robots, imaging/ video
		Robots
Video	Video streaming, live video feed	Video communication from wireless clip-on cameras used in building fire rescue
		Images or video to assist remote medical support
		Surveillance of incident scene by fixed or remote-controlled robotic devices
		Assessment of fire/flood scenes from airborne platforms
Imagery	High-resolution imagery	Downloading earth exploration – satellite images

Annexure 2: Submarine cable-wise list and activated capacity (Gbps)

Table A.2: Submarine cable-wise list and activated capacity (Gbps)

No. of cables	Name of cable system	Location of CLS	Lit capacity (Gbps)		Activated capacity (Gbps)	
			2020	2021	2020	2021
1	AAE-1 (Asia Africa Europe-1)	Mumbai	6,590	7,110	5,250	5,750
2	BBG (Bay of Bengal Gateway)	Chennai and Mumbai	23,100	23,800	12,830	15,900
3	Bharat Lanka Cable System	Tuticorin	40	40	0	30
4	EIG (Europe India Gateway)	Mumbai	4,800	6,400	3,554	3,759
5	FALCON (FLAG Alcatel-Lucent Optical Network-1)	Mumbai	4,210	4,150	4,210	4,150
6	FALCON (FLAG Alcatel-Lucent Optical Network-2)	Trivandrum	170	70	40	30
7	FLAG Europe Asia (FEA: Fibr-Optic Link Around the Globe)	Mumbai	50	50	42	23
8	GBICS (Gulf Bridge International Cable System)	Mumbai	260	260	98	98
9	Network I2I	Chennai	16,730	27,230	14,078	22,760
10	IMEWE (India-Middle East-Western Europe)	Mumbai (2)	9,432	13,805	4,209	4,684
11	MENA (Middle East & North Africa)	Mumbai	2,700	2,700	2,670	2,670
12	SAT3/WACS/SAFE	Cochin	480	480	30	34
13	SEA Cable+TGN EA (SEACOM)	Mumbai	3,520	4,620	3,430	4,470
14	SEA ME WE 3 (South-East Asia - Middle East - Western Europe 3)	Mumbai and Cochin	680	680	59	56
15	SEA ME WE 4 (South-East Asia - Middle East -Western Europe 4)	Chennai and Mumbai	20,640	17,515	4,473	4,546
16	TGN Gulf	Mumbai	260	360	230	320
17	TIISC (Tata Indicom India-Singapore Cable System)	Chennai	7,680	14,600	7,480	14,520
Total			**101,342**	**123,870**	**62,681**	**83,800**

Source: TRAI, 2022 (https://trai.gov.in/sites/default/files/CP_23122022.pdf)

Annexure 3: State-/UT-wise telecommunication subscriber base (wireline + wireless) in India as of March 2024

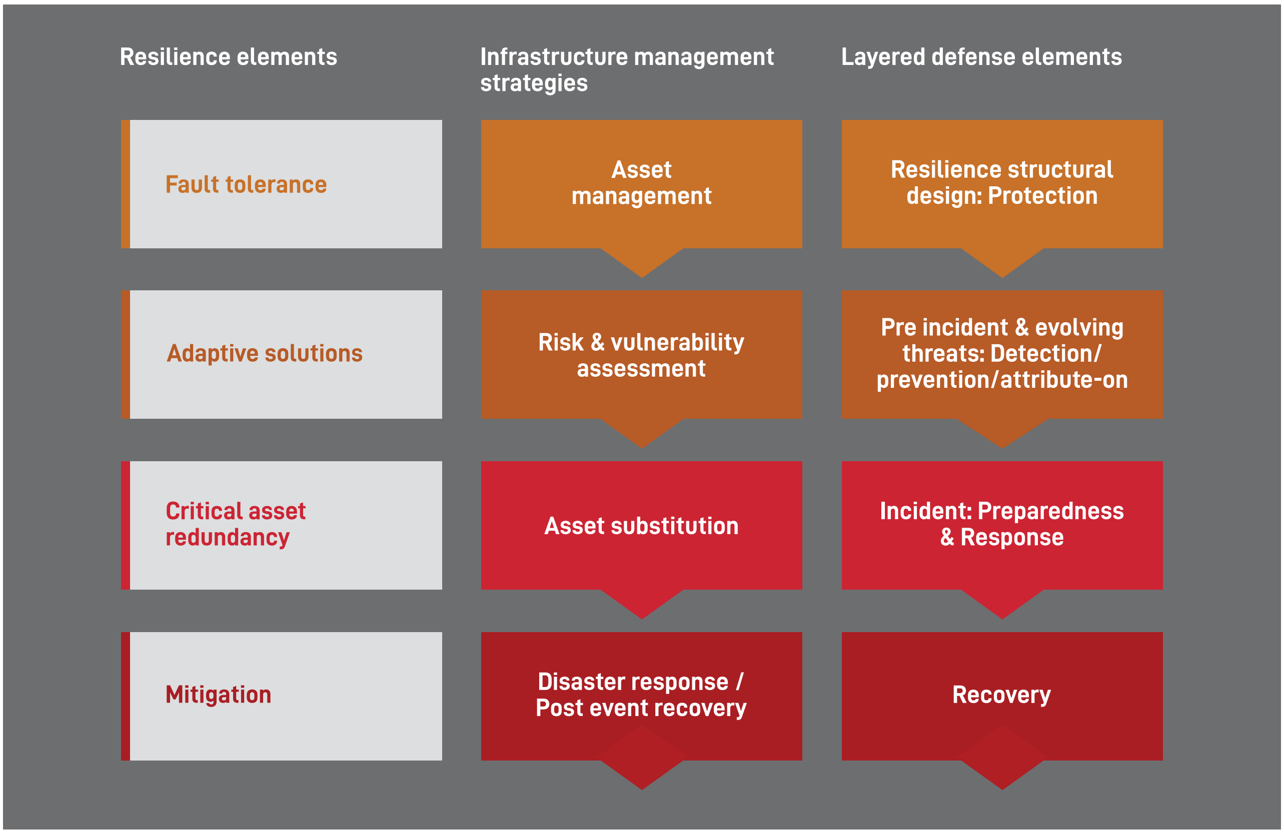
Table A.3: State/UT-wise telecommunication subscriber base (wireline + wireless)

States/UT	Total (in million)	Rural (in million)	Urban (in million)
Andhra Pradesh	45.09	24.79	20.3
Arunachal Pradesh	1.29	0.86	0.43
Assam	26.7	17.08	9.63
Bihar	71.57	50.29	21.27
Chhattisgarh	21.2	10.42	10.78
Goa	2.53	0.86	1.67
Gujarat	66.61	25.3	41.31
Haryana	36.42	12.63	23.78
Himachal Pradesh	8.97	5.77	3.19
Jharkhand	24.88	13.97	10.91
Karnataka	70.33	25.49	44.84
Kerala	43.73	19.31	24.42
Madhya Pradesh	60.05	26.92	33.13
Maharashtra incl. Mumbai	130.23	42.29	87.94
Manipur	2.47	0.99	1.47
Meghalaya	2.65	1.65	1
Mizoram	1.42	0.54	0.89
Nagaland	1.71	0.88	0.84
Odisha	34.2	22.35	11.84
Punjab	34.67	12.25	22.43
Rajasthan	67.35	35.95	31.4
Sikkim	0.81	0.49	0.31
Tamil Nadu	80.12	24.11	56.01
Telangana	42.37	17.15	25.21
Tripura	3.27	1.71	1.56
Uttar Pradesh (UPE + UPW)	166.78	89.69	77.09
Uttarakhand	12.62	6.45	6.17
West Bengal incl. Kolkata	81.74	36.24	45.5
Andaman and Nicobar Islands	0.55	0.26	0.28
Chandigarh	2.01	0.04	1.97
Dadra & Nagar Haveli and Daman & Diu	0.95	0.32	0.62
Delhi	40.25	0.44	39.81
Jammu and Kashmir	11.98	5.72	6.26
Ladakh	0.5	0.28	0.22
Lakshadweep	0.07	0.02	0.05
Puducherry	1.22	0.38	0.84

Source: TRAI (2024)[62]

Annexure 4: Details of global resilience frameworks

Framework 1 - Infrastructure Resilience: A Risk-Based Framework



Focus area: Critical infrastructure

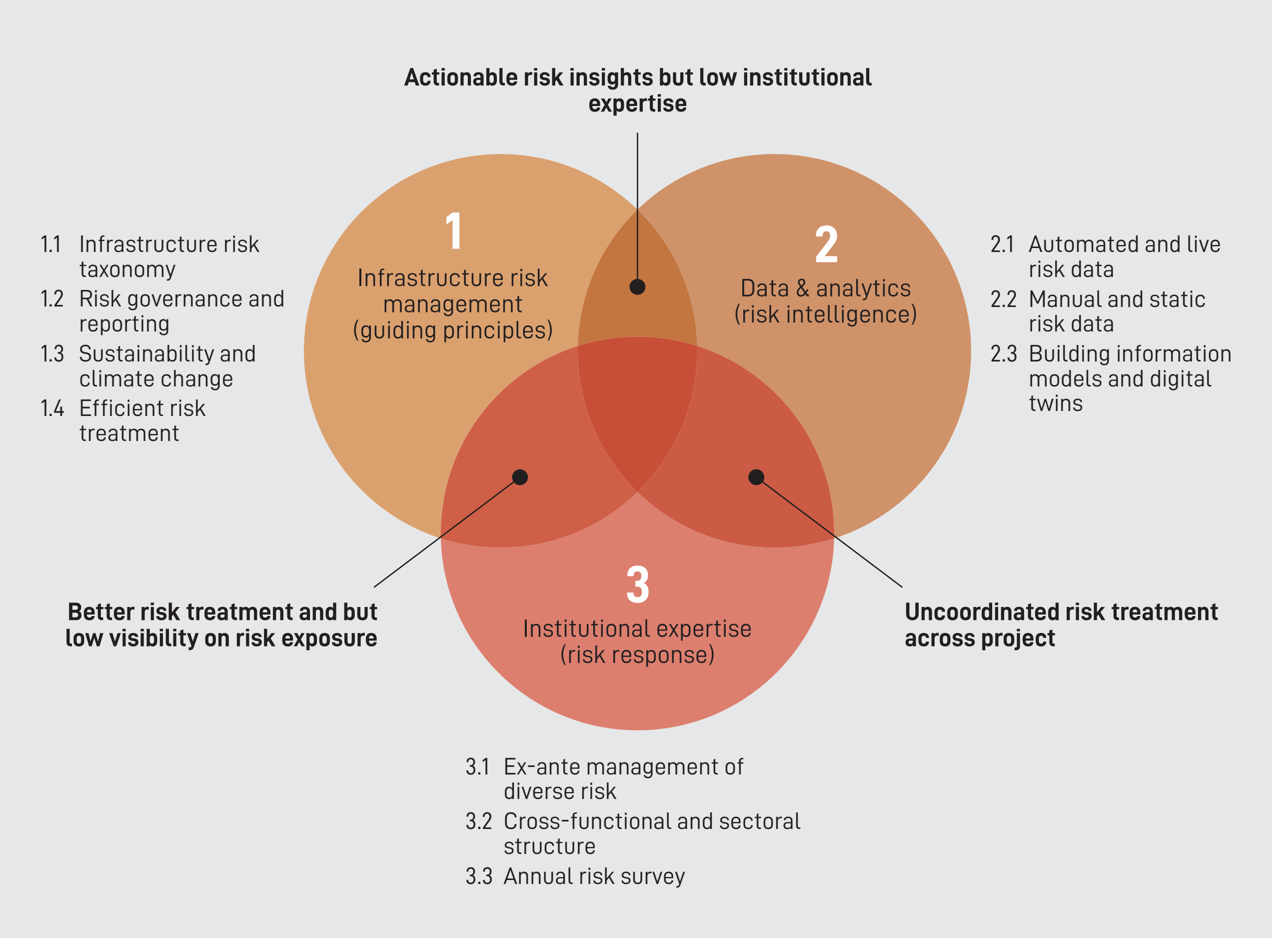
Approach: Risk based lifecycle process for critical infrastructure vulnerabilities

Description

- The cornerstone of the framework is a risk-based layered defence.
- Analyzes the likelihood of threats or hazards occurring and the potential severity of their consequences
- Its layered defence principles involve implementing multiple layers of protection to mitigate risks. This approach aims to create redundancy and prevent single points of failure.
- The emphasis is on considering resilience throughout the entire infrastructure lifecycle – from design and construction to operation and maintenance.

Key components identified: Use a lifecycle approach for resilient infrastructure through systematic risk assessment and following a risk-layered defence.

Framework 2 - Infrastructure Resilience: De-risking Transport Infrastructure Projects in India



Focus area: Transport infrastructure

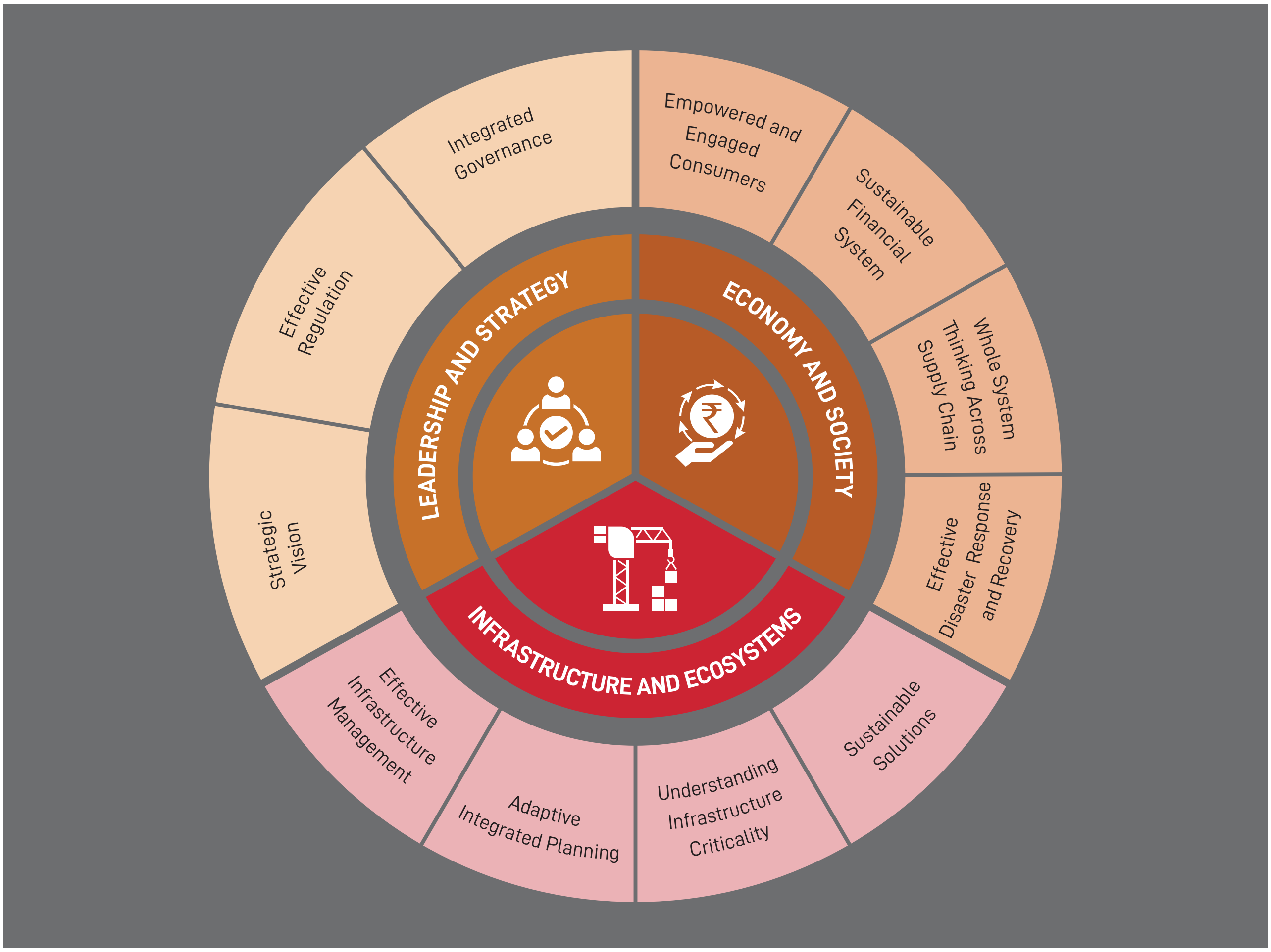
Approach: A life-cycle approach to risk and resilience

Description

- A structured risk-resilience framework can help address operational blind spots in infrastructure projects.
- Proactive risk management approach by following a shift towards 'ex-ante risk management', meaning identifying and mitigating risks before they escalate into problems
- A tailored approach based on the unique vulnerabilities of different infrastructure sectors (e.g., roads, railways, ports, etc.)
- Annual risk surveys to document risk treatment improvements and inform decision-making during crises. This implies a continuous risk assessment and adaptation process.
- Leveraging data from government bodies to map major risks, indicating a data-driven approach to risk assessment.

Key components identified: Robust risk analysis in the asset lifecycle to prioritize decisions and protect stakeholder value.

Framework 3 - Future-Proofing Energy Systems: The Energy Resilience Framework



Focus area: Energy infrastructure

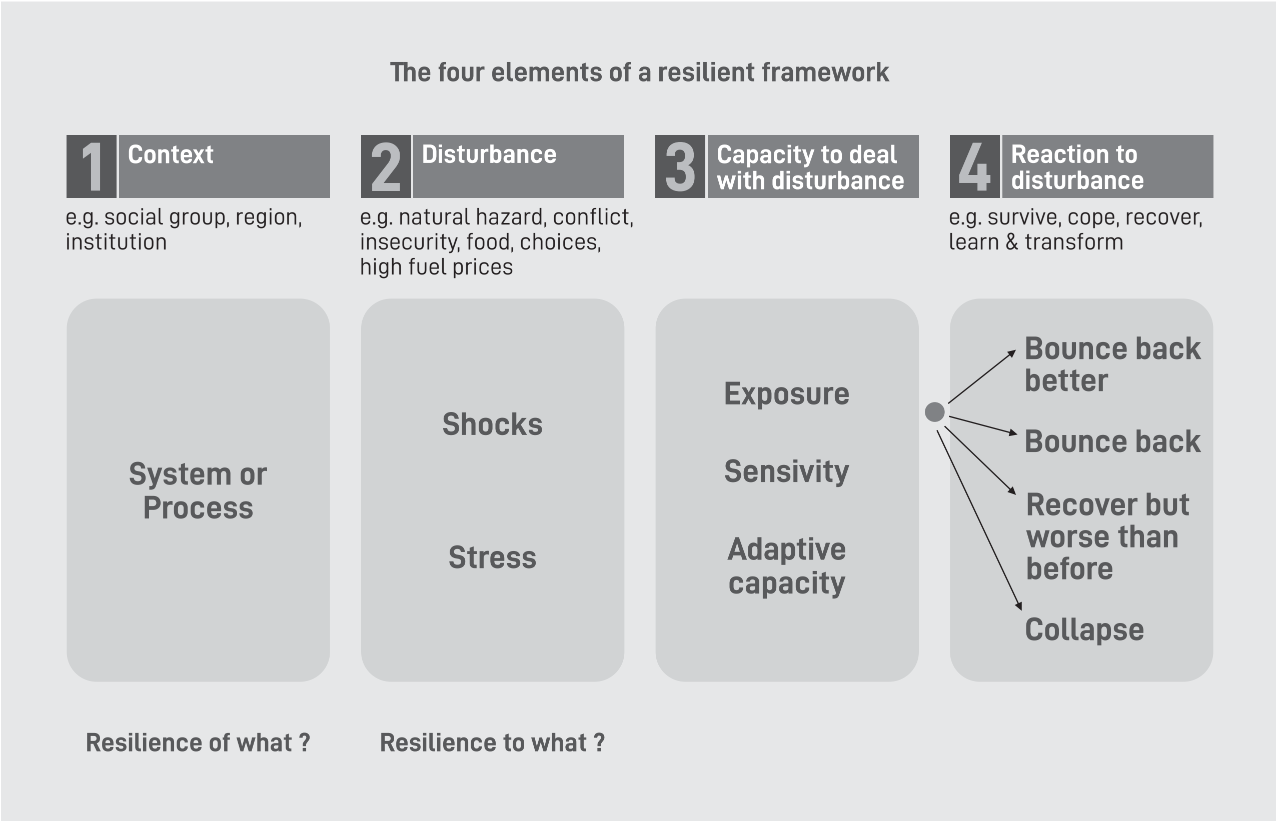
Approach: Balanced attention to tech and non-tech factors for resilience

Description

- There is no one-size-fits-all solution for energy resilience; solutions must be customized to specific needs.
- It is crucial for the energy system to have features such as diversity, redundancy, flexibility and adaptability.
- It is important to adapt resilience solutions by applying valuable lessons learned, which will lead to further improvement.
- We also need to assess the resilience of critical infrastructure and establish guidelines for policies and regulations that support a more resilient energy system.

Key components identified: Dynamic and context-specific technical and non-technical aspects are essential for building energy resilience.

Framework 4 - DFID's Disaster Resilience Framework



Focus area: Resilience to disasters

Approach: Holistic, proactive and partnership-driven

Description

- Resilience-building strategies tailored to the specific context, considering local vulnerabilities, capacities and needs
- Shared understanding and coordinated action among various stakeholders involved in disaster resilience
- Prioritizing proactive measures like early warning systems and preparedness initiatives for timely and effective disaster response
- Securing reliable and long-term funding for resilience-building programmes
- Integrating disaster resilience into broader development and humanitarian efforts

Key components identified: Enhance resilience and recovery for the system or process concerned.

Framework 5 - Infrastructure Resilience Planning Framework

Focus area: Critical infrastructure

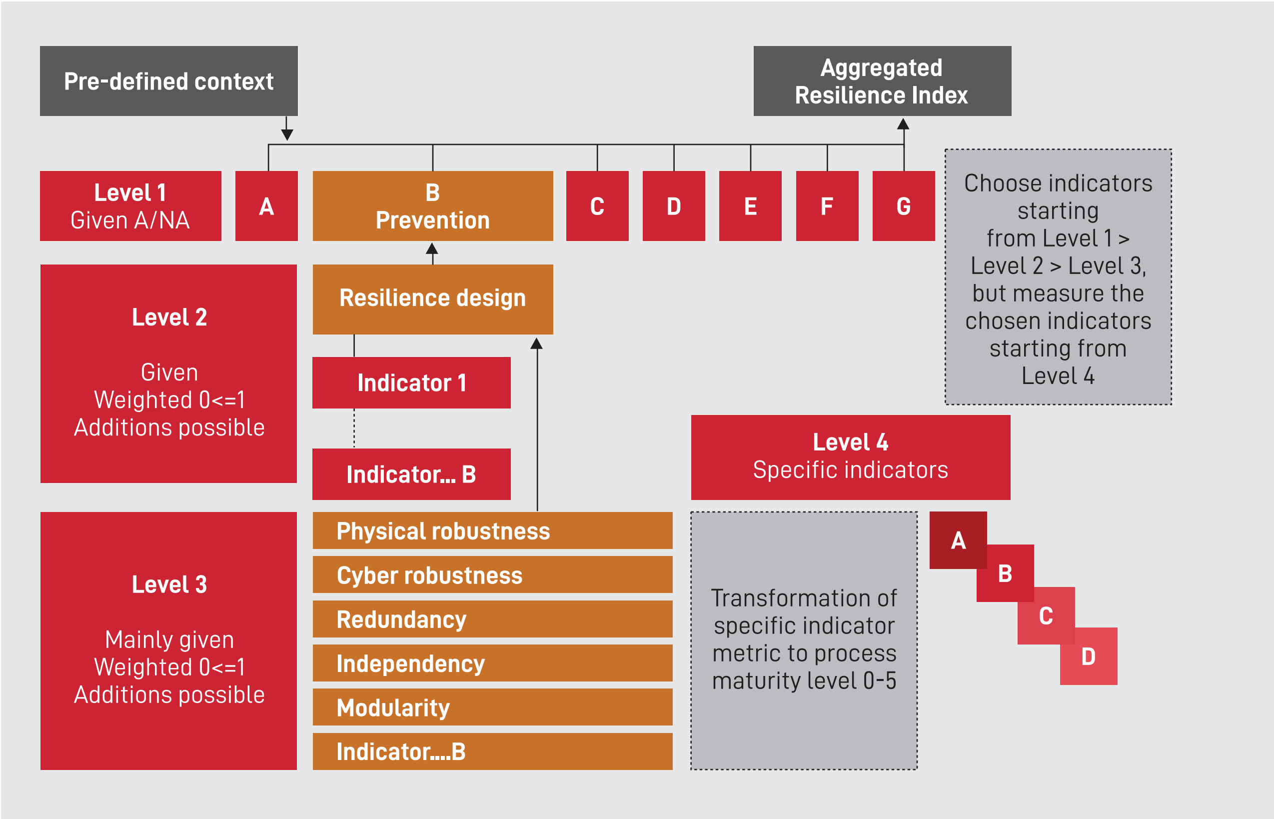
Approach: Understand risks, identify entry, inform policy & investment decisions

Description

- A collaborative planning group, engage stakeholders and gather relevant information
- Classify the most critical infrastructure systems for the community's well-being and identify interdependencies between them
- Evaluate the likelihood and potential impact of various threats and hazards to critical infrastructure
- Prioritize mitigation strategies and resilience-building actions to address identified risks
- Put the plan into action, monitor its effectiveness and adjust as needed

Key components identified: A comprehensive, integrated approach to infrastructure resilience can reduce repetitive losses and mitigate hazard impacts.

Framework 6 - Critical Infrastructure Resilience Index



Focus area: Critical infrastructure

Approach: Weighted & holistic way to evaluate infrastructure

Description

- Adaptable for various sectors and facilities as it is tailored to specific needs and can be customized to address specific hazards and scenarios
- A balanced approach towards organizational and technological resilience emphasizes the organizational aspects (procedures and planning) and technological aspects (redundancy and design) of resilience
- Quantitative and qualitative evaluation combines quantitative data with qualitative assessments to provide a comprehensive picture of resilience
- Use process maturity levels as a uniform metric to compare and aggregate different resilience indicators

Key components identified: Evaluate specific infrastructure parts, individual indicators, or hazard-specific resilience.

Framework 7 - DHS Resilience Framework

Focus area: Critical infrastructure

Approach: : Informed, risk-based decision making

Description

- Establishing and executing continuity plans to uphold critical operations amid disruptions, ensuring seamless functioning
- Adapting to dynamic conditions and fortifying resilience to effectively navigate various forms of disruptions
- Acknowledging the significance of fostering collaboration and partnerships among government entities, private sectors and communities at large
- Taking proactive measures to mitigate risks and bolster resilience before potential events occur
- Guaranteeing the presence of robust response and recovery mechanisms to reduce the impact of disruptions to the minimum extent possible

Key components identified: Leadership, coordination, preparedness, prevention, response and recovery are essential for minimizing disruptions.

Framework 8 - USAID's Climate-Resilient Development

Scope	**Establishes development context and focus** Identifies: • Priority development goals and key inputs to achieving them • Climate and non-climate stressors • Needs and opportunities
Assess	**Enhances understanding about vulnerability** • Defines vulnerability assessment questions • Selects methods • Assesses vulnerability • Provide actionable roadmap
Design	**Identifies, evaluates, and selects adaptation options** • Identifies adaptation options • Selects evaluation criteria • Evaluates adaptation options • Selects an adaptation option or portfolio of options
Implement & manage	**Puts adaptation into practice** • Builds on established implementation & management practices • Adopts a flexible approach to account for continuing change • Incorporate climate information into baseline values & indicators
Evaluate & adjust	**Tracks performance and impact** • Builds on established evaluation practices • Measures performance • Evaluates impacts of actions on vulnerability • Informs adjustments to adaptation strategies

Focus area: Development decision-making

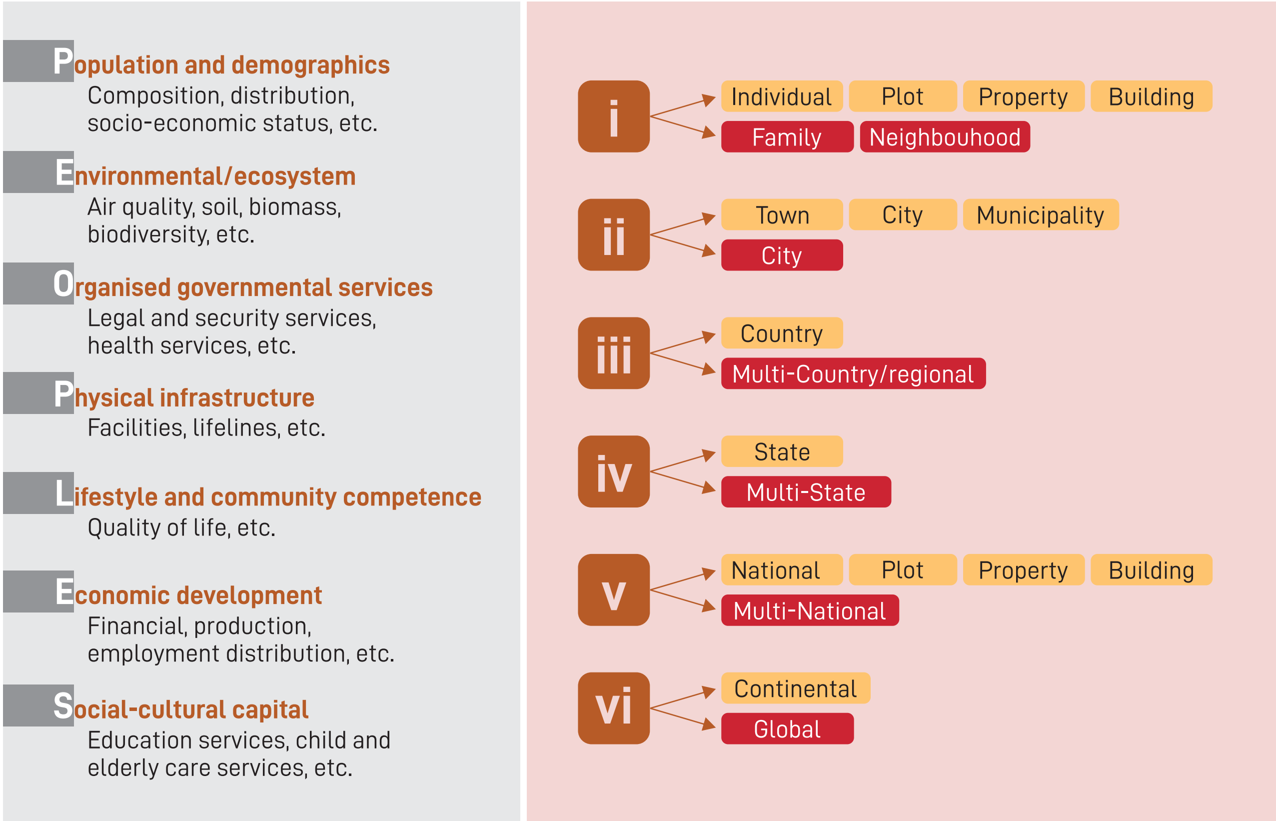
Approach: "Development-first" approach

Description

- Assess the potential impacts of climate change on development goals and vulnerable populations
- Enhance the capacity of individuals, communities and institutions to adapt to climate change
- Include climate change considerations in development planning, policies and investments
- Adaptive management allows adjustments based on new information and changing conditions
- Encourage partnerships and collaboration among stakeholders to effectively address climate change

Key components identified: Understanding climate risks, strengthening adaptive capacity, integrating climate resilience and promoting collaboration are essential for effective climate action.

Framework 9 - The PEOPLES Resilience Framework



Focus area: Community resilience

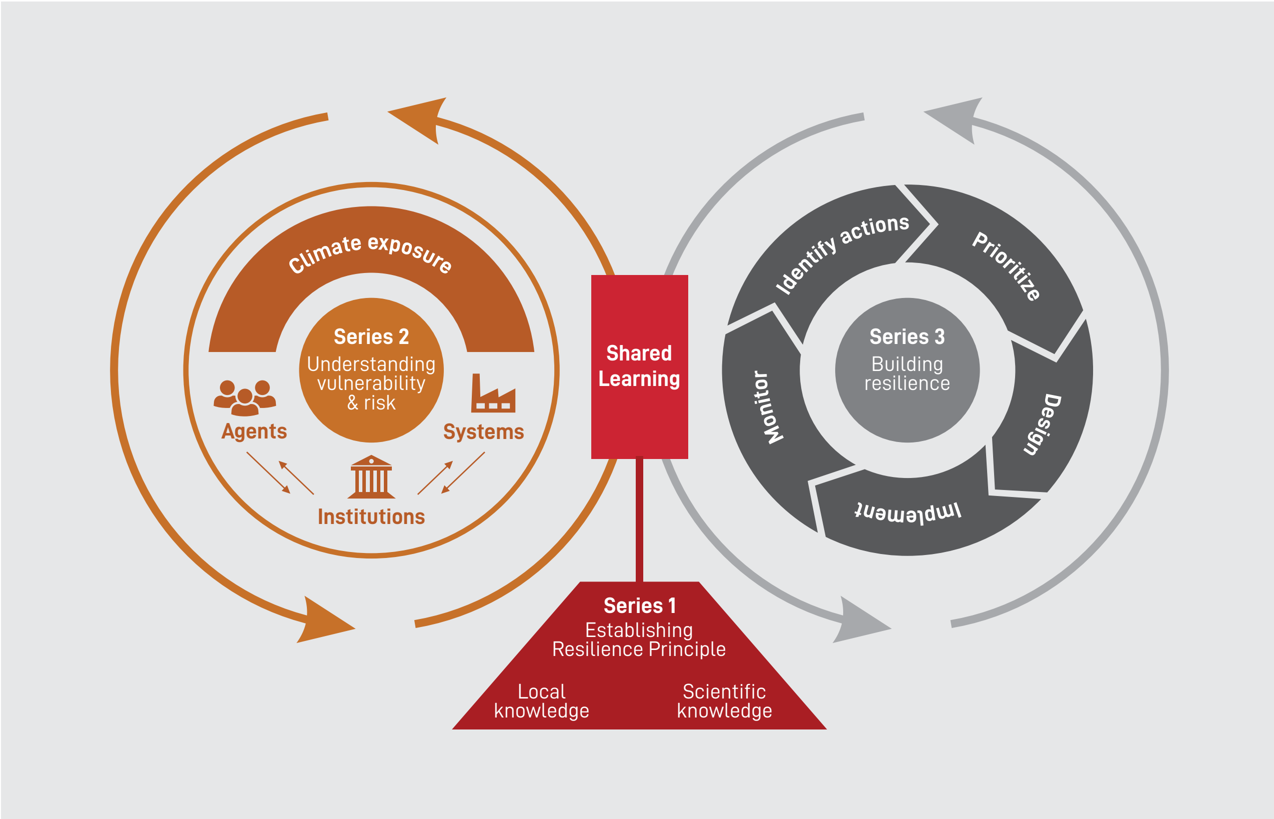
Approach: Quantitatively measure and model sustainable development & DRR

Description

- Seven dimensions of resilience include the following:
  - Population and demographics
  - Environmental/ecosystem services
  - Organized governmental services
  - Physical infrastructure
  - Lifestyle and community competence
  - Economic development
- Measure each dimension using specific metrics and indicators. These quantifiable measures reflect the state or condition of that particular dimension.
- Use an objective and data-driven understanding of resilience levels
- Local knowledge, social capital and community capacity are crucial in building resilience
- Monitor the integration of disaster reduction measures and institutionalization of recovery at each of those scales providing parameters

Key components identified: A comprehensive, measurable and actionable approach is essential for understanding and enhancing community resilience in the face of a changing world.

Framework 10 - The Climate Resilience Framework



Focus area: People, systems, institutions

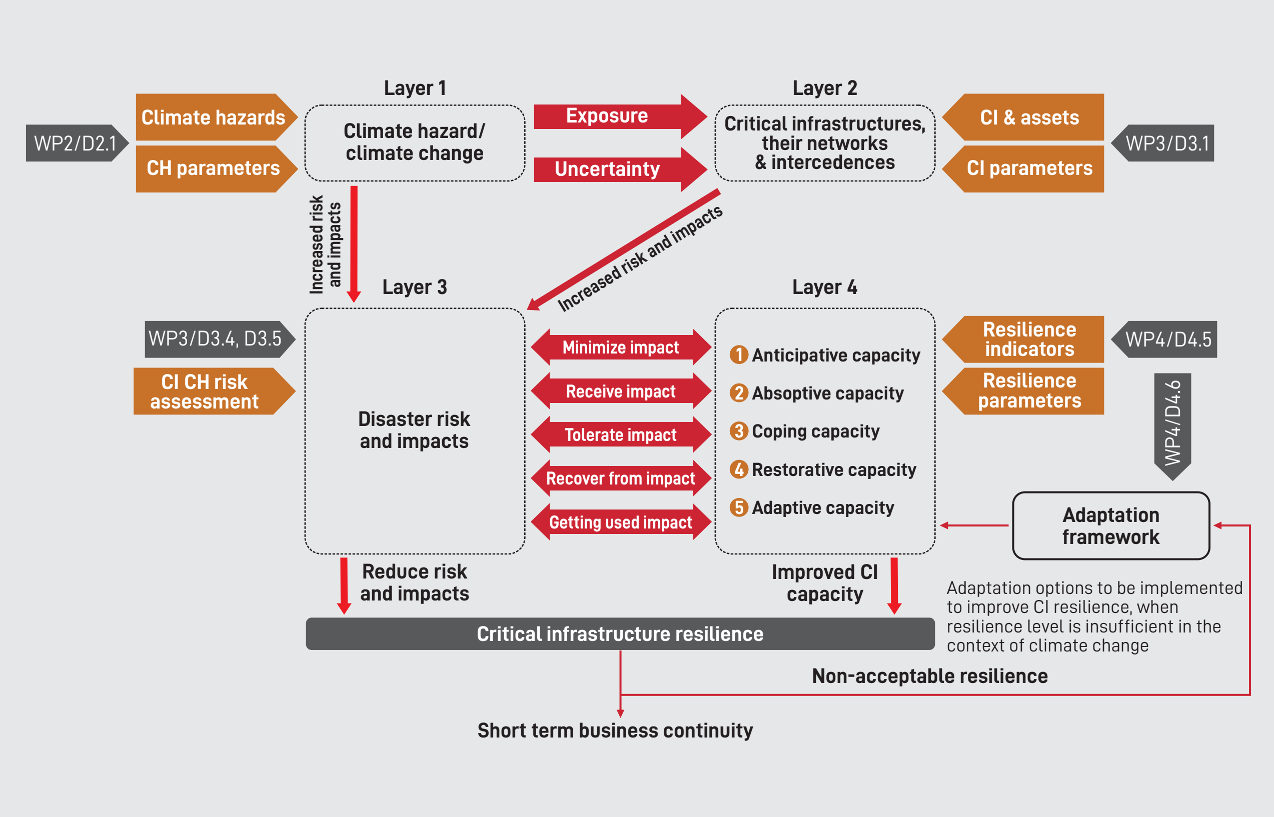
Approach: Systems-based collaborative approach to building resilience

Description

- A structured way to assess climate vulnerabilities and risks, even with uncertainties
- Assess vulnerabilities and risks within a specific location and community
- Develop and implement tailored interventions to address identified challenges
- Continuously evaluate and improve resilience strategies based on shared experiences and new information
- Emphasize participatory process involving a wide range of stakeholders to ensure a shared understanding of climate challenges and potential solutions

Key components identified: Build networked resilience to address climate change.

Framework 11 - Resilience Framework of Critical Infrastructure



Focus area: Critical infrastructure

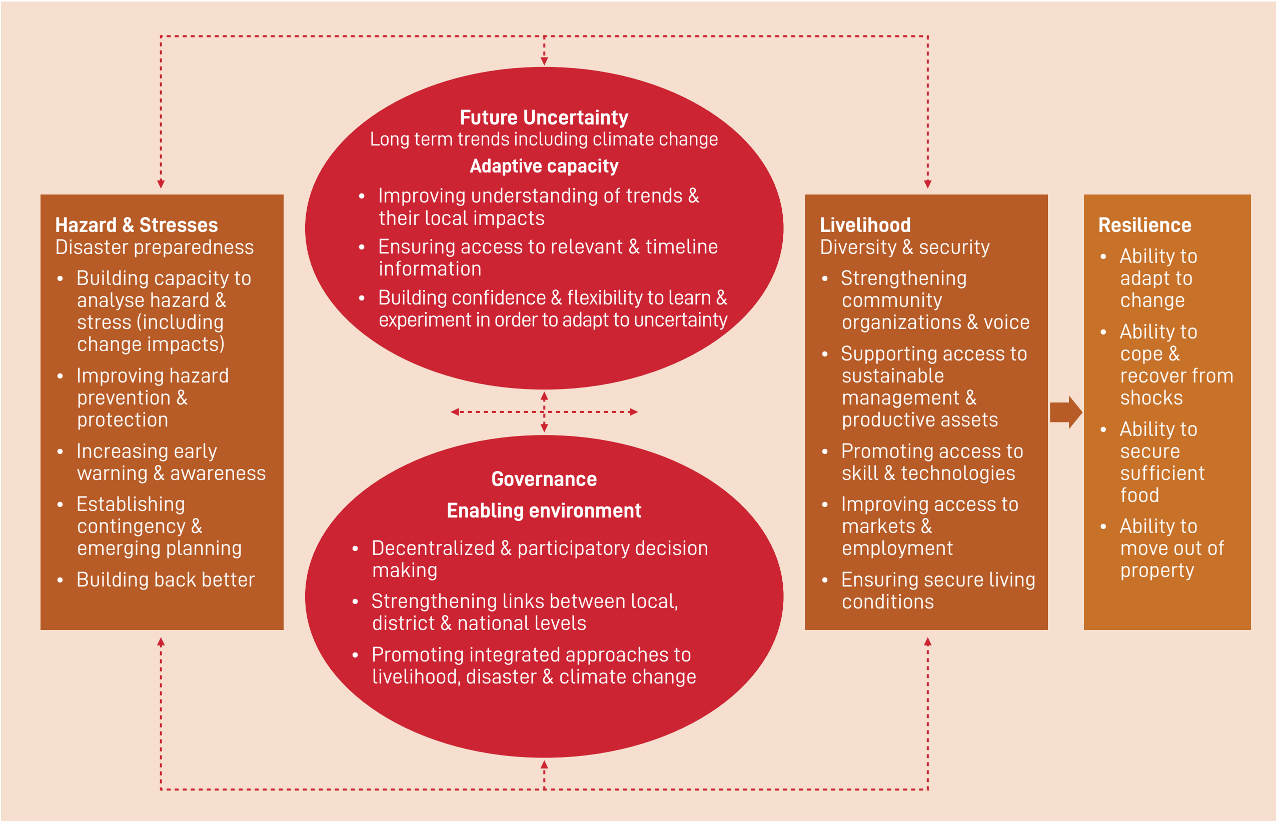
Approach: Independent and interdependent risk layers

Description

- Critical infrastructure resilience relies on a layered risk approach considering climatic hazards, climate change, critical infrastructure networks, interdependencies and associated risks and impacts.
- Each layer is fed with different data and parameters to determine the resilience of critical infrastructure and to further improve the level of resilience.
- Improving the capacity of critical infrastructure can help reduce risks and impacts.
- Enhanced capacity and reduced risks and impacts are essential for achieving critical infrastructure resilience.
- It is important to create a time-bound roadmap for critical infrastructure resilience with short-term goals linked to business continuity and long-term goals linked to adaptation.

Key components identified: Independent and interdependent risk layers work together to create a comprehensive risk management strategy.

Framework 12 - Vulnerability to Resilience (V2R) Framework



Focus area: Demography and systems

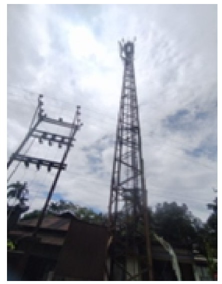
Approach: Multi- level approach

Description

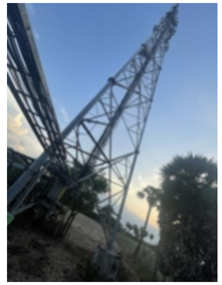
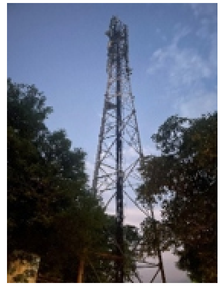
- The V2R considers four key components for incorporation within the framework to tackle the causes and consequences of vulnerability, which include exposure to hazards and stresses, fragile livelihoods, future uncertainty and weak governance.
- Build capacity of poor people in relation to multiple hazards and an uncertain future and thus could be used in the context of community resilience
- Strengthen resilience through improved governance mechanisms

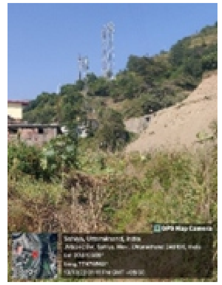
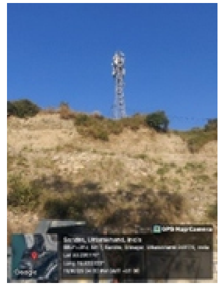
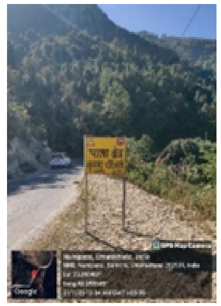
Key components identified: Governance mechanism is crucial to high-level resilience management.

Annexure 5: Most vulnerable telecommunications towers across 5 states

S. No.	Image ID	Block/Circle	Village/Town	Village/Town		Nature of damage/impact/ potential vulnerability associated with the asset	Description / Any other information	Image
				Latitude	Longitude			
1.	IMG-20230905-WA0049	Chabua Revenue Circle	Pukhurijan, Chabua, Dibrugarh, Assam	27.556334 °N	95.219366 °E	The picture depicts a telecommunications tower in Pukhurijan region, Chabua.	This region is highly prone to land erosion due to floods every year.	
2.	IMG-20230907-WA0008	Haflong Revenue Circle	Haflong, Dimahasao, Assam	25.158557 °N	93.017505 °E	Image (a1-2) depicts BSNL tower in Mahadev Tilla, the highest peak in Dima Hasao District. The region is highly vulnerable to landslides and wind hazards.	NA	
3.	IMG-20230908-WA0042	Borkhola Development Block	Ujangram - Dholcherra Rd, Cachar, Assam	24.92777 °N	92.745055 °E	NA	Image of telecom tower clicked enroute Ujangram - Dholcherra Rd. The block (Population: 1, 25,000) is highly vulnerable to storms & cyclones (February-May), floods (May- September), and lightning (August- September). General - It was informed during the block consultation that during the Assam Floods in 2022, a DG set site in the block got completely inundated up to 6 feet. It took about 15-20 days for the water to recede.	

S. No.	Image ID	Block/Circle	Village/Town	Village/Town		Nature of damage/impact/ potential vulnerability associated with the asset	Description / Any other information	Image
				Latitude	Longitude			
4.	IMG_3857	Naliya Mandavi	Una, Gujarat	20.742343 °N	71.010013 °E	Physical damage in router was reported during Cyclone Tauktae (2021).	NA	
5.	IMG_3840	Fatsar village	Gir Gadhada, Gir Somnath, Gujarat	20.930775 °N	70.983409 °E	Physical damage to the telecommunications tower was reported during Cyclone Tauktae (2021).	Telecommunications site Impacted during Cyclone Tauktae (2021)	
6.	IMG_3732	SH 23, Lalpur block	Lalpur, Jamnagar, Gujarat	22.20929 °N	69.97245 °E	Physical damage to the building and antenna was reported during Cyclone Biparjoy, and the restoration of the antenna took 3 weeks. The region also experiences frequent lightning incidents.	NA	

S. No.	Image ID	Block/Circle	Village/Town	Village/Town		Nature of damage/impact/ potential vulnerability associated with the asset	Description / Any other information	Image
				Latitude	Longitude			
7.	IMG_3145	Uthamasoz-hamangalam road	Chidambaram, Cuddalore, Tamil Nadu	11.43910 °N	79.77469 °E	During Flood event in 2021, water inundation of ~1m was reported	a) Tower Height: ~45 m. b) Prone to inundation. c) Flood 2021, inundation ~1 m	
8.	IMG_3154	NH 32, Kurinjipadi	Cuddalore, Tamil Nadu	11.57309 °N	79.71281 °E	During past flood event , water inundation was reported at this site	Prone to inundation due to recurrent flooding	
9.	IMG_3165	East Coast Road, Manjakuppam	Cuddalore, Tamil Nadu	11.75082 °N	79.76072 °E	Physical damage was reported to the telecommunications tower during Cyclone Thane (2011)	Impacted during Cyclone Thane (2011).	

S. No.	Image ID	Block/Circle	Village/Town	Village/Town		Nature of damage/impact/ potential vulnerability associated with the asset	Description / Any other information	Image
				Latitude	Longitude			
10.	20231013_11156 PMByGPSMap Camera.jpg	Kalsi	Dehradun, Uttarakhand	30.610908 8888888 °N	77.87656194 44444 °E	The area is prone to landslide.	Block is vulnerable to landslides resulting in considerable damage to the roads and other infrastructure. Some villages have been identified to be relocated.	
11.	20231011_43159PMBy GPSMapCamera.jpg	Srinagar, Pauri Garhwal District	Srinagar, Uttarakhand	30.23017388 88888 °N	78.82322194 44444 °E	Telecommunications tower in the rockfall zone.	The area is prone to rockfall due to the presence of unstable rock mass, high rainfall and the slopes.	
12.	20231101_103413amBy GPSMapCamera.jpg	Pithoragarh	–	29.61845083 33333 °N	80.259145 °E	The area falls in frost zone	Maximum towers in Paala kshetra (Frost area)	

S. No.	Image ID	Block/Circle	Village/Town	Village/Town		Nature of damage/impact/ potential vulnerability associated with the asset	Description / Any other information	Image
				Latitude	Longitude			
13.	21256	21256	Rangeilunda block	19.25143 °N	84.863402 °E	Telecommunications tower had broken from middle portion during Cyclone Phailin 2018	New tower has been commissioned	
14.	35835	Nausira	Tirtol block	20.307275 °N	86.329912 °E	The region is vulnerable to cyclone	–	
15.	40910	Badakundra	Gop block	19.94112 °N	86.049614 °E	The region is vulnerable to cyclone	–	

Bibliography

1 Grand View Research, 2023, Market Analysis Report, https://www.grandviewresearch.com/industry-analysis/global-telecom-services-market#

2 International Telecommunication Union, 2024, Measuring Digital Development: Facts & Figures, https://www.itu.int/hub/publication/D-IND-ICT_MDD-2024-4/

3 GSMA, 2023, Policy spotlight: India, https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/policy-spotlight-india/

4 Invest India, 2024,Telecom Industry Scenario, https://www.investindia.gov.in/sector/telecom#:~:text=As%20per%20GSMA%2C%20India%20is,include%2088%20Mn%205G%20connections.

5 Portulans Institute (University of Oxford, Said Business School),2023,Network Readiness Index-India, https://download.networkreadinessindex.org/reports/countries/2023/india.pdf

6 Modor Intelligence, 2024, India Telecom Market Size (2024 - 2029), https://www.mordorintelligence.com/industry-reports/india-telecom-market/market-size,

7 India briefing, 2024, India's Telecom Sector: Market Outlook and Regulatory Landscape, https://www.india-briefing.com/news/indias-telecom-sector-market-outlook-and-regulatory-landscape

8 Ministry of Economic & IT, 2019, Report on India's Trillion Dollar Digital Opportunity, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1565669

9 GSMA, 2022, India on the road to digital nation, https://www.gsma.com/about-us/regions/asia-pacific/wp-content/uploads/2022/09/India-report-FINAL-WEB.pdf

10 India Investment grid, telecommunication snapshot, Invest in Telecommunication Sector in India | IIG

11 DoT dashboard, Ministry of Communication, 2024, https://dot.dashboard.nic.in/DashboardF.aspx

12 UN ESCAP, 2019, Economic and Social Survey of Asia, https://www.unescap.org/sites/default/files/publications/Economic_Social_Survey%202019.pdf

13 Institute for Economics and Peace, 2020, Ecological threat register, https://www.visionofhumanity.org/wp-content/uploads/2020/10/ETR_2020_web-1.pdf

14 Jacek Rak et.al, 2021, Disaster resilience of optical networks: State of the art, challenges, and opportunities, https://www.sciencedirect.com/science/article/pii/S1573427721000163

15 Marshall, A., Wilson, C. A., & Dale, A. (2023). Telecommunications and natural disasters in rural Australia: The role of digital capability in building disaster resilience. Journal of Rural Studies, 100, 102996. https://doi.org/10.1016/j.jrurstud.2023.03.004

16 World Bank, 2019, Resilient Industries: Competitiveness in the face of disaster, https://documents1.worldbank.org/curated/en/682501604040773738/pdf/Resilient-Industries-Competitiveness-in-the-Face-of-Disasters.pdf

17 UNDRR, Disaster risk and resilience, https://www.un.org/en/development/desa/policy/untaskteam_undf/thinkpieces/3_disaster_risk_resilience.pdf

18 ITU, 2020, The Last-mile Internet Connectivity Solutions Guide, https://www.itu.int/dms_pub/itu-d/opb/tnd/D-TND-01-2020-PDF-E.pdf

19 TRAI, 2022, Recommendations on Regulatory Framework for Promoting Data Economy Through Establishment of Data Centres, Content Delivery Networks, and Interconnect Exchanges in India, https://trai.gov.in/sites/default/files/Recommendations_18112022_0.pdf

20 TeleGeography. 2022, Sub-Marine Cable map, https://submarine-cable-map-2022.telegeography.com/

[21] TRAI, 2022, Consultation Paper on Licensing Framework and Regulatory Mechanism for Submarine Cable Landing in India, https://www.trai.gov.in/sites/default/files/CP_23122022.pdf

[22] TRAI, Recommendations on Telecommunications Infrastructure Policy, 2011. https://www.trai.gov.in/sites/default/files/2024-09/Rec_Infrastructurel.pdf

[23] DoT Dashboard, 2024, https://dot.dashboard.nic.in/DashboardF.aspx

[24] TRAI, The Indian Telecom Services Performance Indicators, January–March 2024 https://www.trai.gov.in/sites/default/files/QPIR_04072024_0.pdf

[25] The Economics Times, 2024, Telcos free to take a call on shutting down 2G services, https://economictimes.indiatimes.com/industry/telecom/telecom-news/telcos-free-to-take-a-call-on-shutting-down-2g-services-says-dot/articleshow/107923624.cms?from=mdr

[26] Department of Telecommunication, 2022, Satellite communication reforms, https://dot.gov.in/sites/default/files/Satelite%20Reforms%202022.pdf?download=1

[27] TRAI, Consultation Paper on Terms and Conditions for the Assignment of Spectrum for Certain Satellite-Based Commercial Communication Services, https://www.trai.gov.in/sites/default/files/CP_27092024.pdf

[28] The Hindu, 2024, Optical fibre-based connectivity, https://www.thehindubusinessline.com/data-stories/data-focus/indias-wired-broadband-subscribers-jump-20-to-394-million/article68057927.ece/amp/

[29] Telecommunication engineering Centre, Standard and specification, https://www.tec.gov.in/standards-specifications

[30] ITU, End-to-end quality of service for voice, https://www.itu.int/rec/T-REC-G.1028-201906-I/en

[31] European standard, https://single-market-economy.ec.europa.eu/single-market/european-standards_en

[32] Department of Telecommunication. 2024, Digital Bharat Nidhi, https://usof.gov.in/en/ongoing-schemes

[33] Telecommunication Engineering Centre, 2022, Roll out of small cells for 5g network by leveraging street furniture, https://www.tec.gov.in/pdf/Studypaper/TEC%20Committee%20Report%20on%20Rollout%20of%20small%20cells.pdf

[34] Ministry of Communications, 2024, Development of 'Cell-Free' 6G Access Points, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2036236#:~:text=In%20a%20significant%20step%20towards,Roorkee)%20and%20Indian%20Institute%20of

[35] Ministry of Communication, 2024, The Telecommunications Act 2023: Ushering in a New Era of Connectivity, https://pib.gov.in/PressReleasePage.aspx?PRID=2031057#:~:text=2023%20w.e.f.%20today%2C%20i.e.%2C%20July,and%20for%20matters%20connected%20therewith.

[36] Ministry of Communication, 2024, Atmanirbhar Bharat and driving Design and Make in India vision, https://pib.gov.in/PressReleasePage.aspx?PRID=2010473#:~:text=Centre%20for%20Development%20of%20Telematics,subsidiary%20of%20Qualcomm%20Incorporated%2C%20to

[37] Ministry of Communication, 2024, Rating of Properties for Digital Connectivity Regulations, 2024, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2068149

[38] Invest India, 2023, Bharat 6G Vision: India's Push for the Next Generation of Telecom Technology, https://www.investindia.gov.in/team-india-blogs/bharat-6g-vision-indias-push-next-generation-telecom-technology

[39] Department of telecommunication, 2020, Standard Operating Procedure for Telecommunication services for responding to disasters, https://dot.gov.in/sites/default/files/2021_01_06%20SOP-2020%20DM.pdf?download=1

[40] PwC's on-ground stakeholder consultation

[41] ISGF. 2015. White Paper. Case Studies on Power Line Carrier Communication Implementation in India Document Number: ISGF – WG 4/2015/00004 Version 1.0 https://indiasmartgrid.org/isgf/public/banner_img/1671695404nJkrsTqj01NX3Sb9Ex2VuHBz5away9fOuP7tkUrB.pdf

[42] PwC's on-ground stakeholder consultation

[43] PwC's on-ground stakeholder consultation

[44] Storm Surge, Indian Tsunami Early Warning System, https://tsunami.incois.gov.in/TEWS/AboutStormSurge.jsp

[45] Cyclone hazard climatology, 2023, https://rsmcnewdelhi.imd.gov.in/uploads/climatology/hazard.pdf

[46] BMTPC, Wind hazard map, https://bmtpc.org/DataFiles/CMS/file/VAI2019/MAP/windmap/wind_jpg/WIND_INDIA1.jpg

[47] NDMA, Natural hazard flood, https://www.ndma.gov.in/Natural-Hazards/Floods

[48] NDMA, Lighting resilience in India, https://ndma.gov.in/sites/default/files/NLJuly24/images/LIGHTNING-RESILIENCE-IN-INDIA.pdf

[49] Barami et.al., 2013, Infrastructure Resiliency: A Risk-Based Framework, https://rosap.ntl.bts.gov/view/dot/10009

[50] Swiss Re, 2023, Infrastructure resilience De-risking transport infrastructure projects in India, https://www.swissre.com/dam/jcr:91b175c6-9b67-4826-b2f6-55fcbb3e174e/2023-07-sri-expertise-publication-infrastructure-resilience-india.pdf

[51] ARUP, 2019, Future-proofing energy systems: The Energy Resilience Framework, https://www.arup.com/globalassets/downloads/insights/e/energy-resilience-framework/energy-resilience-framework.pdf

[52] DFID, Defining Disaster Resilience: A DFID Approach Paper, https://www.fsnnetwork.org/sites/default/files/dfid_defining_disaster_resilience.pdf

[53] American Cyber Agency, 2022, Infrastructure Resilience Planning Framework (IRPF), https://www.cisa.gov/resources-tools/resources/infrastructure-resilience-planning-framework-irpf

[54] CIRI,2017, https://ciri.illinois.edu/news/ciri-announces-2017-projects

[55] US Dept. of Homeland Security, 2018, DHS RESILIENCE FRAMEWORK Providing a roadmap for the Department in Operational Resilience and Readiness, https://www.dhs.gov/sites/default/files/publications/dhs_resilience_framework_july_2018_508.pdf

[56] USAID, 2014, Climate-resilient development: A framework for understanding and addressing climate change, https://pdf.usaid.gov/pdf_docs/pbaaa245.pdf

[57] UNDRR, 2013, The PEOPLES resilience framework: An integrated quantitative measure and modeling of sustainable development and disaster risk reduction, https://www.undrr.org/publication/peoples-resilience-framework-integrated-quantitative-measure-and-modeling-sustainable

[58] ISET International, 2014, https://www.i-s-e-t.org/climate-resilience-framework

[59] Climate Adapt, 2018, A pan-European framework for strengthening critical infrastructure resilience to climate change (EU-Circle), https://climate-adapt.eea.europa.eu/en/metadata/projects/a-pan-european-framework-for-strenghtening-critical-infrastructure-resilience-to-climate-change

[60] Katherine Pasteur, From Vulnerability to Resilience A framework for analysis and action to build community resilience, https://www.fsnnetwork.org/sites/default/files/from_vulnerability_to_resilience_v2r_pasteur_2011.pdf

[61] cost benefit analysis, https://www.cbabuilder.co.uk/CBA1.html#:~:text=A%20third%20type%20of%20CBA,as%20with%20ex%20post%20CBA.

[62] TRAI, 2024. https://oldwebsite.trai.gov.in/sites/default/files/Report_14082024.pdf

[63] Kathuria, R., Mansi, Richa, K., & Ujjwal, S. (2018). Growth Dividends of Digital Communications: The Case for India. https://icrier.org/pdf/Digital_Communications.pdf

[64] Telecommunication Engineering Center (2022). Roll out of small cells for 5G network by leveraging street furniture - to Facilitate a Standard Approach for the Proliferation of Dense Small Cell Infrastructure. Department of telecommunication. under Ministry of Communication. Govt of India

[65] ICRA. (2024). Indian Telecom Industry. Delhi. India

[66] Kiran Rathee. (2024). Telcos free to take a call on shutting down 2G services, says DoT. Economic Times. https://economictimes.indiatimes.com/industry/telecom/telecom-news/telcos-free-to-take-a-call-on-shutting-down-2g-services-says-dot/articleshow/107923624.cms?from=mdr

[67] ToI. (2024). Big boost for India's internet quality! Three large undersea cable projects to expand capacity by more than four times.https://timesofindia.indiatimes.com/business/india-business/big-boost-for-indias-internet-quality-three-large-undersea-cable-projects-to-expand-capacity-by-more-than-four-times/articleshow/112672969.cms

[68] TRAI. (2022). Consultation Paper on Licensing Framework and Regulatory Mechanism for Submarine Cable Landing in India. Delhi.India https://www.trai.gov.in/sites/default/files/CP_23122022_0.pdf

[69] TRAI. (2023). Recommendations on Licensing Framework and Regulatory Mechanism for Submarine Cable Landing in India https://trai.gov.in/sites/default/files/Recommendation_19062023.pdf

[70] TRAI. (2012). Consultation Paper on Review of Telecom Consumers Protection Regulations (TCPR).

[71] TRAI. (2024). Recommendations on Telecommunication Infrastructure Sharing, Spectrum Sharing and Spectrum Leasing https://trai.gov.in/sites/default/files/Recommendation_24042024.pdf

[72] TRAI. (2023). Recommendations on Improving Telecom Infrastructure in Northeastern States of India New Delhi, India https://trai.gov.in/sites/default/files/Recommendations_23092023.pdf

[73] TRAI. (2023). Recommendations on Issues related to Community Radio Stations https://trai.gov.in/sites/default/files/Recommendation_22032023.pdf

[74] TRAI. (2022). Recommendations on USE OF STREET FURNITURE FOR SMALL CELL AND AERIAL FIBER DEPLOYMENT https://trai.gov.in/sites/default/files/Recommendations_29112022_0.pdf

[75] The International Cable Protection Committee. 2016, Submarine Cables and BBNJ, https://www.un.org/depts/los/biodiversity/prepcom_files/ICC_Submarine_Cables_&_BBNJ_August_2016.pdf

[76] Makrakis, Nikolaos & Psarropoulos, Prodromos & Tsompanakis, Yiannis. (2023). GIS-Based Optimal Route Selection of Submarine Cables Considering Potential Seismic Fault Zones. Applied Sciences. 13. 2995. 10.3390/app13052995.

[77] https://www.telecoms.com/broadband/overcoming-the-challenges-of-subsea-cable-route-planning

[78] TRAI. (2024). Highlights of Telecom Subscription Data as on 29th February, 2024 . https://www.trai.gov.in/sites/default/files/PR_No.18of2024_0.pdf

[79] TEC. (2008). Disaster Management Guidelines for Telecommunications. https://www.tec.gov.in/pdf/GR3/Disaster_Management_guidelines_for%20Telecommunications.pdf

[80] TRAI (2011). Recommendations on Telecommunications Infrastructure Policy. https://www.trai.gov.in/sites/default/files/Rec_Infrastructurel.pdf

[81] TRAI. (2019). Consultation Paper on Review of Scope of Infrastructure Providers Category-I (IP-I) Registration. https://www.trai.gov.in/sites/default/files/CP_NSL_Infra_16082019.pdf

[82] CDRI. (2023). Global Infrastructure Resilience: Capturing the Resilience Dividend, a Biennial Report from the Coalition for Disaster Resilient. https://www.cdri.world/upload/biennial/CDRI_Global_Infrastructure_Resilience_Report.pdf

[83] CIF Program: Pilot Program for Climate Resilience (PPCR). (2024). PPCR: Resilience and Infrastructure. https://cif.org/sites/cif_enc/files/knowledge-documents/26-03-2024_deep_dive_infrastructure_v3.pdf

[84] ITU. (2024). Telecommunication networks and infrastructure resilience assessment in Haiti. ISBN: 978-92-61-38011-3, https://www.itu.int/hub/publication/d-ldc-ictldc-2024-01/

[85] ITU-T. (2022). Standardization Roadmap on Natural Disaster Management: Trends and Gaps in Standardization. https://www.itu.int/dms_pub/itu-t/opb/fg/T-FG-AI4NDM-2022-PDF-E.pdf

[86] Zawadzki A., Mehrotra P., Westgate S., Kaemmerer S., and Hegazy M. (2023). Adaptation and Resilience Through Land Transport Infrastructure Systems. https://www.bcg.com/publications/2023/adaptation-and-resilience-in-land-transport-infrastructure

[87] USA, AT&T, FIRSTNET, https://www.firstnet.com/content/dam/firstnet/collateral/firstnet-firstcall-magazine-public-safety-network.pdf

[88] Spain, High Altitude Platform Systems, https://www.gsma.com/solutions-and-impact/technologies/networks/wp-content/uploads/2022/02/HAPS-Towers-in-the-skies-draft-v-2.1-clean.pdf

[89] World Bank. (2019). Lifelines: The Resilient Infrastructure Opportunity, https://openknowledge.worldbank.org/entities/publication/c3a753a6-2310-501b-a37e-5dcab3e96a0b

[90] World Bank. (2019). No Broken Link: The Vulnerability of Telecommunication Infrastructure to Natural Hazards, https://documents1.worldbank.org/curated/en/951991560791754833/pdf/No-Broken-Link-The-Vulnerability-of-Telecommunication-Infrastructure-to-Natural-Hazards.pdf

[91] Department of telecommunication. (2023-24). Annual Report, https://dot.gov.in/sites/default/files/Annual%20Report%202023.pdf

[92] ITU. (2022). Global Connectivity Report, https://www.itu.int/itu-d/reports/statistics/global-connectivity-report-2022/

[93] Bedi, Navjot Singh. (2019). RF spectrum allocation process in India, https://cenjows.in/wp-content/uploads/2022/03/Re-Spectrum-Allocation_Refiesign-by-Brig-Navjot-Singh.pdf

[94] ITU. (2020). Women, ICT and emergency telecommunication: opportunities and constraints, https://sdgs.un.org/sites/default/files/2021-03/ITU%20report_Women_ICT%20and%20emergency.pdf

[95] P.Di Vito et.al., European Spece Agency. (2018). HAPs Operations and Service provision in Critical Scenarios, https://arc.aiaa.org/doi/pdf/10.2514/6.2018-2504

[96] TRAI. (2023). A white paper on 6 Ghz band, https://tcsr.trai.gov.in/doc/White_Paper_25092023.pdf

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