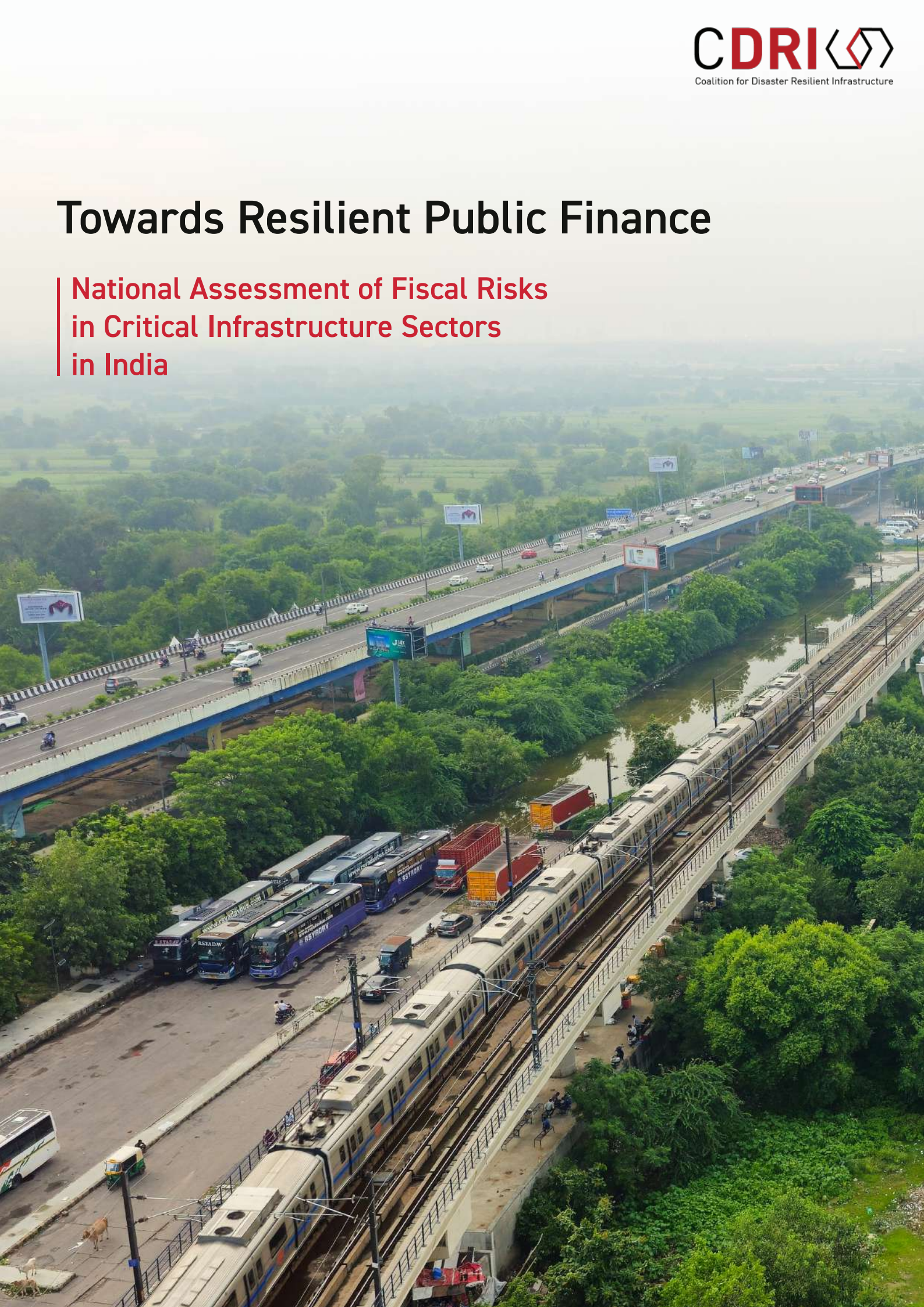
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Towards Resilient Public Finance

National Assessment of Fiscal Risks in Critical Infrastructure Sectors in India



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National Assessment of Fiscal Risks in Critical Infrastructure Sectors in India



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Foreword



Amit Prothi

Director General
Coalition for Disaster Resilient Infrastructure

India's vast geography and climatic diversity make it one of the most disaster-prone countries in the world. From floods, cyclones, and droughts to earthquakes, landslides, and heatwaves, the country faces recurrent and overlapping hazards that affect millions each year. With 27 of 36 states and union territories classified as disaster-prone, and more than 60 percent of its landmass exposed to earthquakes and floods, the fiscal and developmental implications of disasters are far-reaching. Climate change is amplifying these risks by raising temperatures, intensifying rainfall extremes, and accelerating coastal erosion. Recent events such as the 2018 Kerala floods and Cyclone Fani in 2019 have shown how disasters can cause extensive infrastructure losses, disrupt essential services, and impose significant recovery costs. Each event diverts public resources from long-term development priorities towards immediate response and reconstruction, creating fiscal stress across both central and state budgets. For a fast-growing economy with expanding infrastructure needs, these compounding shocks underscore the urgency of building financial preparedness. Strengthening disaster risk financing systems is not only vital for protecting lives and assets but also for safeguarding India's long-term fiscal stability and resilience.

As part of the Coalition for Disaster Resilient Infrastructure's commitment to strengthening resilience in infrastructure systems globally, we launched a model disaster risk finance study in four countries to assess fiscal risks associated with disasters in critical infrastructure sectors. This study for India is among the first in the region to systematically link disaster-related impacts on infrastructure to fiscal outcomes. Key recommendations to enhance disaster risk financing strategies and strengthen institutional capacity to manage contingent liabilities in infrastructure are also provided. The study aims to serve as a benchmark for disaster risk financing by providing a methodology to assess the economic and fiscal implications of disasters, the performance of existing financing mechanisms, and the critical importance of forward-looking, risk-informed public investment and budgeting practices. We hope this assessment will serve as a useful tool for policymakers, financial planners, and development partners working to build fiscal resilience in India and other similarly vulnerable economies.

We are grateful to our consultant, the Asian Disaster Preparedness Center, and to the Government of India for its guidance and leadership throughout the process. As we collectively move towards resilient and sustainable development pathways, it is imperative that disaster risk finance is integrated into the core of public financial decision-making. This report is a step in that direction.

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Executive Summary

India faces recurrent and escalating fiscal risks from natural hazards, including floods, cyclones, droughts, and landslides. Between 2000 and 2019, more than 300 major disasters were recorded, affecting over 1.2 billion people and causing close to 80,000 fatalities. The scale and frequency of these events—compounded by climate change, rapid urbanization, and high population density—impose mounting economic and fiscal costs on both central and state governments.

This report, prepared under the Coalition for Disaster Resilient Infrastructure's Finance for Resilient Infrastructure Programme (FRIP), examines the fiscal impacts of disasters in India, evaluates trends in disaster risk financing, and identifies opportunities to strengthen financial resilience and preparedness.

India's disaster risk financing landscape has evolved from ad hoc post-disaster allocations toward a more structured system anchored in the Disaster Management Act (2005). The National Disaster Response Fund (NDRF) and State Disaster Response Funds (SDRFs) form the backbone of this framework, providing resources for relief, rehabilitation, and reconstruction. However, allocations have fluctuated considerably, ranging from INR 28,102 million in 2012–13 to INR 185,305 million in 2019-20, and overall resources remain insufficient relative to the scale of recurring losses. Expenditures on disasters, while significant, have not kept pace with the rising fiscal burden from climate and disaster events.

Economic modelling results confirm that disasters have a statistically significant impact on government expenditure, with expenditure increasing by approximately 0.17 percent of GDP (around INR 94–97 billion) in an average disaster year. Changes in central government debt are positive but not statistically significant, suggesting that India largely finances disaster response through budget reallocations and contingency reserves rather than new borrowing. The impacts are most pronounced in the immediate aftermath of disasters, with limited persistence in subsequent years.

The analysis further highlights that monetary damages (% of GDP) are more strongly correlated with fiscal stress than human losses, as measured through Life Years Lost (LYL). This indicates that short-term fiscal impacts are primarily driven by the scale of infrastructure and capital stock damage rather than the indirect social and economic costs of disasters.

India's exposure continues to increase as extreme events become more frequent and severe. Catastrophic disasters such as the 2007 Bihar floods and the 2004 Indian Ocean tsunami demonstrated that a single event can result in fiscal impacts of over INR 200 billion in additional debt and nearly INR 100 billion in expenditure. The fiscal stress from such large-scale events, combined with smaller recurring hazards, underscores the need for a multi-tiered risk-financing strategy that integrates budgetary instruments, insurance, and contingent credit.





Looking ahead, the assessment underscores the importance of strengthening fiscal preparedness through:

1. Enhancing the predictability and adequacy of NDRF and SDRF allocations.
2. Expanding pre-arranged financing instruments, such as contingent credit and risk transfer mechanisms.
3. Integrating disaster-linked fiscal risks into national debt management and macro-fiscal frameworks.
4. Improving data systems and sub-national modelling capacity to capture localized economic and fiscal impacts.
5. Building capacity across central and state institutions for evidence-based disaster risk financing decisions.

India, both at the federal level and the states, has put in strong institutional frameworks and financing mechanisms, However development of layered financing structures and innovative financing instruments can help alleviate fiscal burden and ensure faster disbursements in the post-disaster phase of natural events. Furthermore, by advancing these measures, India can ensure faster recovery, safeguard development investments, and enhance resilience to future climate and hazard shocks.

Chapter 1

Introduction



Introduction

India's vast and varied geography makes it one of the most disaster-prone countries in the world. Stretching from the Himalayas in the north to the Indian Ocean in the south, the country faces a wide range of natural hazards, including cyclones, floods, droughts, landslides, earthquakes, and increasingly frequent heatwaves. Climate change is intensifying these threats, resulting in more frequent, intense, and unpredictable events. Each year, disasters result in significant loss of life and damage to infrastructure, disrupting livelihoods and hindering development progress. These recurring challenges highlight the need for stronger disaster-preparedness systems and climate-resilient infrastructure (UNDRR 2019; IPCC 2022; World Bank 2021).



India's demographic and economic characteristics contribute to its vulnerability. With a population of over 1.4 billion, about 44 percent of people rely on agriculture for their livelihoods (FAO 2020). Although the services and industrial sectors primarily drive the country's economic growth, the high level of dependence on climate-sensitive livelihoods leaves many communities vulnerable to changing weather patterns. Additionally, rapid urbanization and unplanned growth have increased exposure to hazards, especially in expanding cities and ecologically fragile areas. Disasters frequently impose fiscal strain on governments, as funds must often be redirected from planned development projects to emergency response and recovery efforts. If these disaster-related contingent liabilities are not properly anticipated, they can exacerbate public debt and create additional fiscal risks.

The National-Level Assessment of Fiscal Risk Due to Disasters in Critical Infrastructure Sectors project is part of the Coalition for Disaster Resilient Infrastructure's (CDRI) broader initiative to assist member countries in developing effective disaster risk financing (DRF) strategies. Through the Finance for Resilient Infrastructure Programme (FRIP), this project aims to improve financial preparedness for both pre-disaster mitigation and post-disaster recovery. This report evaluates the fiscal risks associated with disasters in India's critical infrastructure sectors, with a primary focus on power and transport, to support evidence-based policymaking and strengthen fiscal resilience.

India has made significant India has made significant progress in recent years to improve disaster risk management and financial preparedness. The National Disaster Management Authority (NDMA), established under the Disaster Management Act (2005), provides the overarching institutional and policy framework for managing disaster risks (Government of India 2005). In support of these efforts, the National Institute of Disaster Management (NIDM) has developed methodologies and operational tools for post-disaster needs assessment (PDNA). In 2019, it released a set of standardized handbooks and standard operating procedures to promote consistent, data-driven approaches to recovery planning across states. Building on this foundation, the current assessment aims to identify the fiscal implications of disasters for India's infrastructure sectors and explore options to enhance financial resilience, helping the country protect its development trajectory in an increasingly uncertain climate.

Fiscal Risk Assessment Framework

The International Monetary Fund (IMF) defines fiscal risk as the economic factors that may cause actual fiscal outcomes to differ from projected or expected ones (IMF 2016). The Organisation for Economic Co-operation and Development (OECD) describes fiscal risks as changes in the expected fiscal outcomes outlined in an economy's annual budget or forecasting documents (OECD 2019). Fiscal risks can arise from macroeconomic shocks or from contingent liability obligations triggered by uncertain events. Therefore, governments must comprehend these risks and prepare for them by conducting financial risk assessments (FRA). This preparation is essential for effective resource allocation in the event of a disaster.

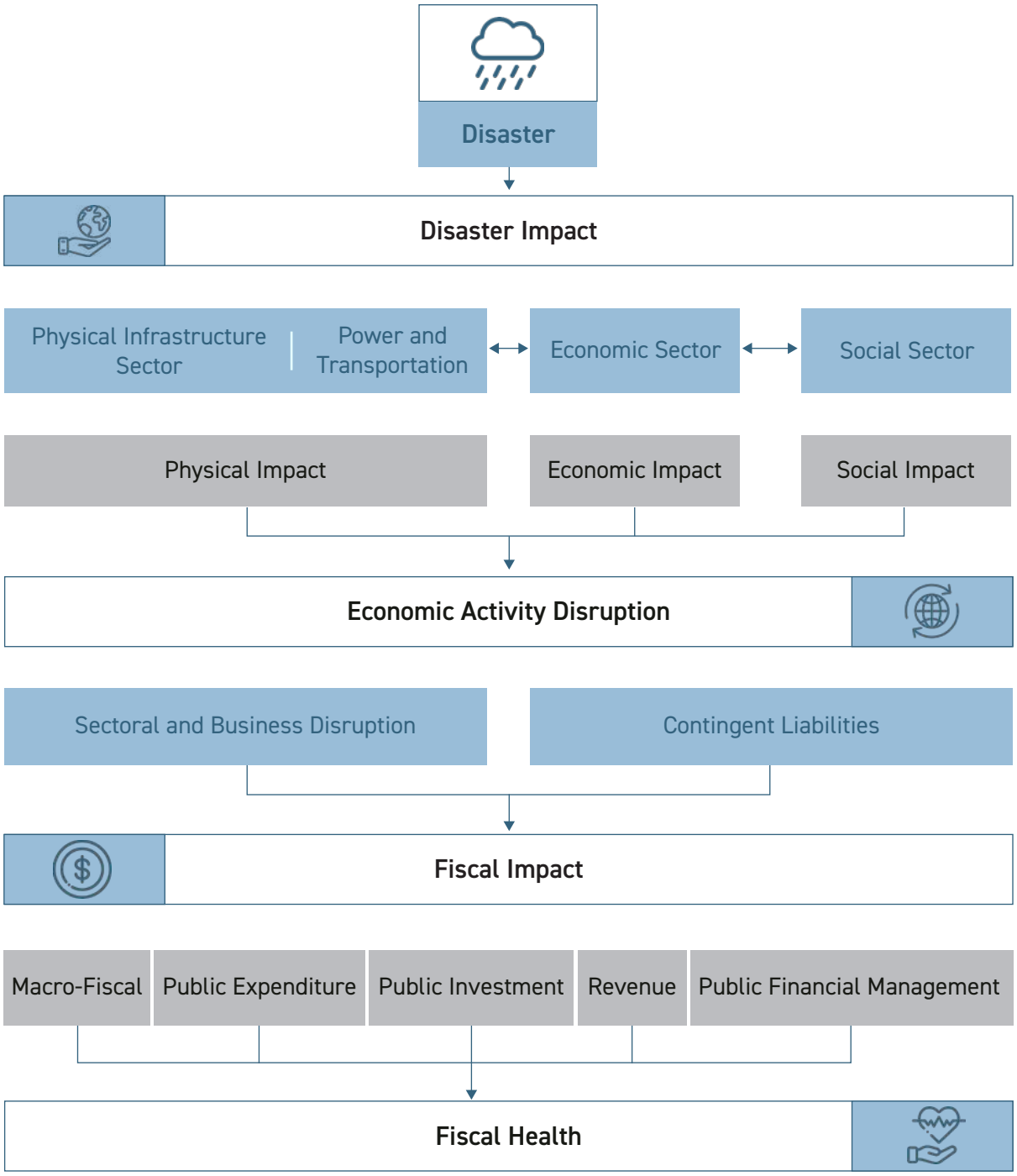
Fiscal risks can arise from various sources, including macroeconomic shocks, financial sector crises, legal challenges, subnational government liabilities, and issues related to state-owned enterprises (SOEs). Disasters can impose substantial costs, averaging 1.5 percent of gross domestic product (GDP) and, in extreme cases, reaching up to 6 percent (Albala-Bertrand 1993), making them a significant source of fiscal risk. Additionally, public-private partnerships (PPPs) and liabilities of private non-financial companies may necessitate government bailouts. According to a study by Bova et al. (2016), disasters impose the second-highest fiscal costs, averaging 1.6 percent of GDP, following financial sector shocks, which account for 9.7 percent. To maintain sound fiscal management and ensure the government's ability to respond effectively in a crisis, it is essential to recognize and manage these risks.

Disasters have significant fiscal implications for governments. According to the Inter-American Development Bank (IDB), fiscal impact channels can be categorized into macro-fiscal, revenue-related, public expenditure, public investment, and public financial management impact (Inter-American Development Bank 2017). Understanding these channels is essential for policymakers to effectively manage the fiscal consequences of disasters.

Figure 1.1 displays a structured framework adopted in this report. The framework illustrates how disasters can have a cascading effect on economic and fiscal stability. It begins with the immediate impact of a disaster, which disrupts physical infrastructure and affects both economic and social sectors. These disruptions lead to interruptions in economic activity, including sectoral and business disruptions, as well as the creation of contingent liabilities for the government. As economic activity declines, various fiscal consequences emerge and are categorized as fiscal impacts. This impact can affect macro-fiscal stability, public expenditure, public investment, revenue, and public financial

management. Ultimately, these cumulative fiscal pressures play a crucial role in determining the government's overall fiscal health.

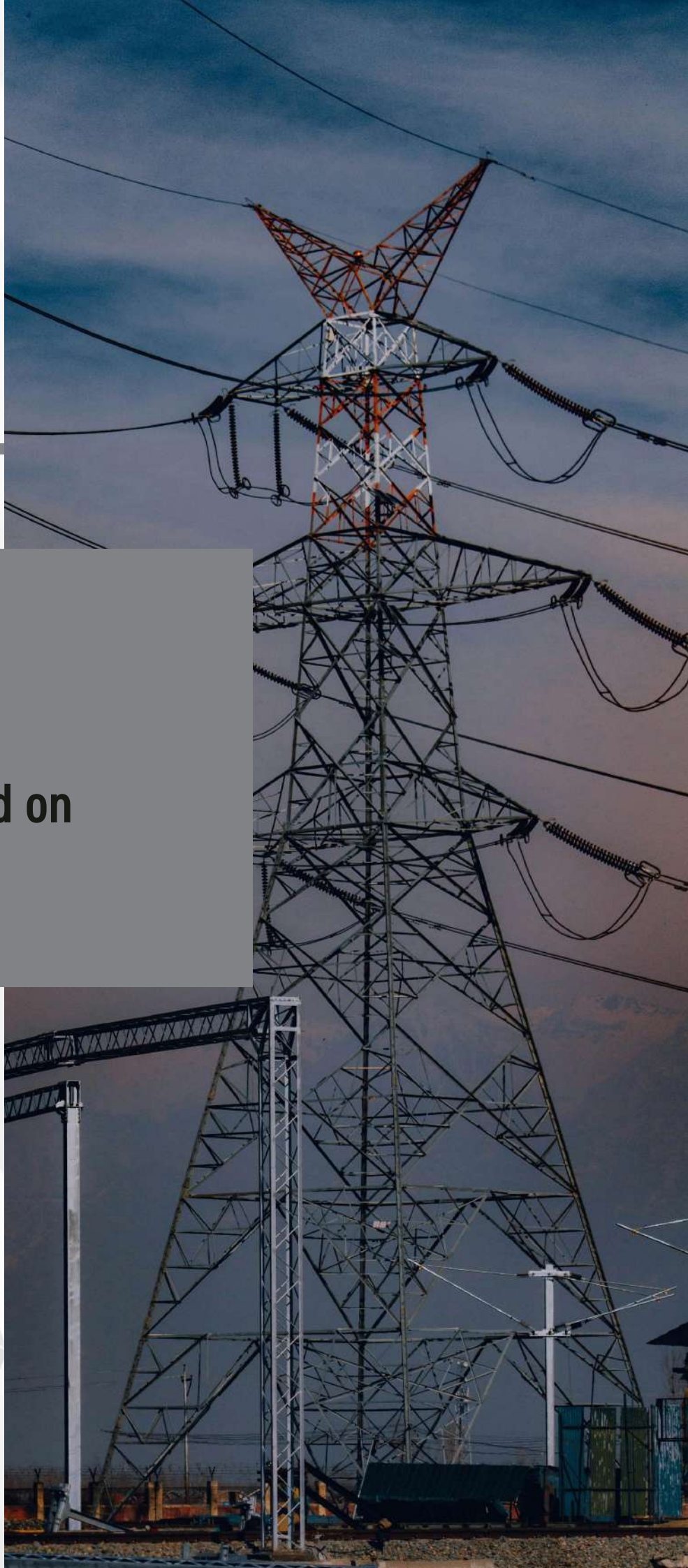
Figure 1.1: Framework for Assessing Fiscal Risk Arising from Disasters



Source: ADPC

Chapter 2

Financial Risk Assessment based on Historical Data



Financial Risk Assessment based on Historical Data

Climate-induced disasters, such as floods, cyclones, and other hazards, can have a devastating impact on human lives, economies, and public finances. These disasters may result in loss of life, displacement of communities, and damage to infrastructure, leading to reduced economic output and increased demand for emergency services, reconstruction, and social welfare and protection programmes. For lower-middle-income and low-income countries, climate-induced extreme weather events contribute to an average increase in the fiscal deficit of 0.8 and 0.9 percent of GDP, respectively (IMF 2023). From a fiscal perspective, the rising frequency and intensity of climate-related disasters present a greater risk of negative fiscal shocks. These disasters put additional strain on public finances, leading to budget deficits and increased public debt. This, in turn, weakens the fiscal stance due to adverse effects on both revenue and expenditure. Consequently, investment projects may be postponed, and fiscal policies may become more cyclical.



Disasters can significantly affect government revenues by negatively affecting economic activity. This often leads to decreased tax and non-tax revenues due to lower tax revenues, disruptions in international trade, and reduced labour hours. However, a post-disaster recovery phase may stimulate economic activity, resulting in a short-term increase in foreign aid or tax revenue. In addition to the immediate changes in revenue and spending, disasters also affect the government's assets and obligations. For example, damage to public infrastructure increases the cost associated with repair or replacement. Unfortunately, many governments do not maintain complete balance sheets that account for non-financial assets, making it more challenging to evaluate the fiscal impact of such disasters.

Between 1994 and 2013, disasters caused an estimated $2.6 trillion[1] in economic losses globally, equivalent 4 percent of global GDP in 2015 (Guha-Sapir, Below, and Hoyois 2016). On average, across a sample of events between 1990 and 2014, the financial impact of disasters on a country's economy was about 1.6 percent of its GDP. In some cases, the costs were significantly higher, with the most severe disasters resulting in losses of up to 6 percent of GDP (Bova et al. 2016). A study by the International

[1] All figures in $ refer to US dollars unless otherwise specified.

Monetary Fund found that the maximum fiscal cost identified was 6 percent of GDP. Various studies show a negative correlation between disasters and economic growth, indicating that such events tend to lower GDP in both the short and long terms. To ensure that governments are adequately prepared for future disasters and do not underestimate their financial impacts, it is essential to improve predictions of potential damage and to conduct better research on low-frequency, high-impact disasters.

Figure 2.1: Fiscal Impact Channels of Disasters



Source: ADPC

As governments borrow money to fund recovery efforts, this can lead to budget deficits and increased public debt. Disasters often result in production losses, disrupt trade, and reduce tax revenue due to lost labour hours and reduced business earnings, which significantly affect government income. To address this, governments must set aside funds for emergency response and recovery. They often share the costs of disasters with local governments, which necessitate further assistance. Public financial management faces challenges in guaranteeing that disaster funds are used effectively and transparently. Additionally, public investment may be adversely affected, as funds may be diverted from future projects to rebuild damaged infrastructure.

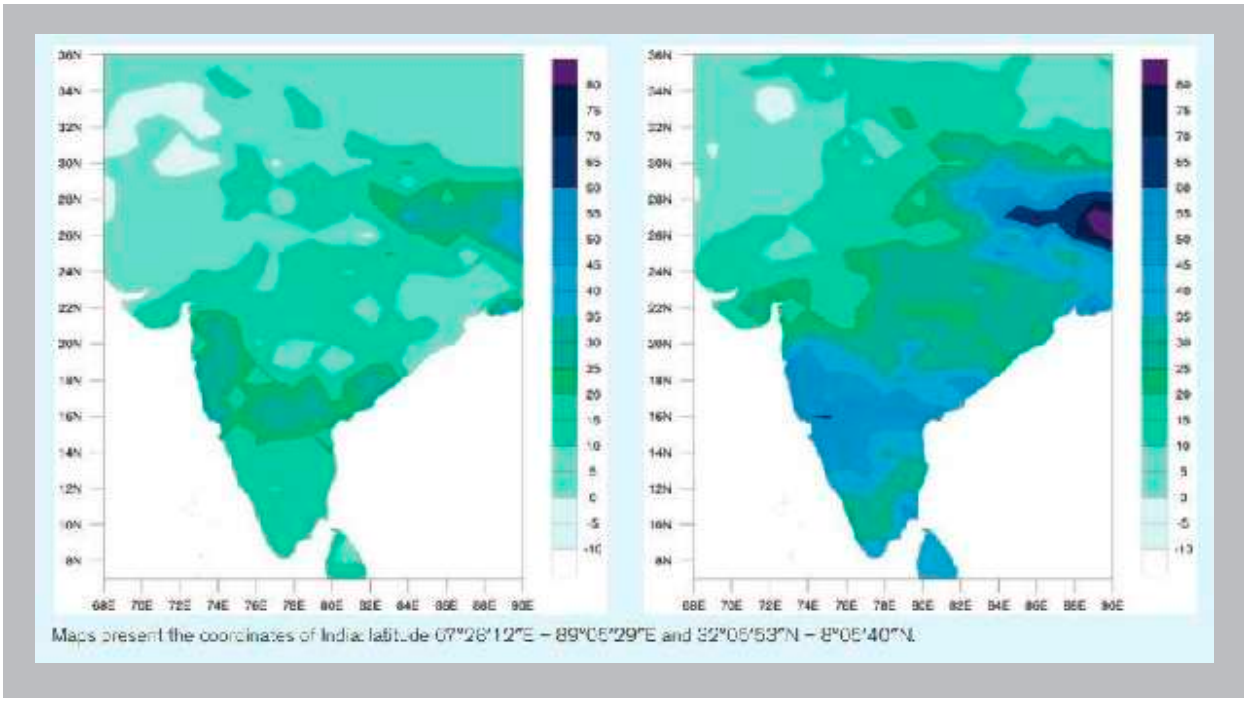
Overview of Impact of Disasters in India

India's vast geography and climatic diversity render it one of the most disaster-prone countries in the world. The country is susceptible to a variety of natural hazards, including earthquakes, floods, droughts, cyclones, landslides, heatwaves, and tsunamis. Many of these events occur frequently and with increasing intensity. Out of the country's 36 states and union territories, 27 are considered disaster-prone (NDMA 2019). Approximately 60 percent of India's landmass is vulnerable to earthquakes of varying intensity, over 8 percent is at risk of flooding, over 68 percent of cultivable land is susceptible to drought, and 5,700 km of coastline is exposed to cyclones (NIDM 2020). These interconnected risks are exacerbated by rapid urbanization, environmental degradation, and unplanned development, thereby increasing exposure and vulnerability.

Climate change is already increasing the frequency and severity of hydrometeorological hazards. Over the past century, the mean annual surface temperature in India has increased by around 0.4°C, with some regions recording up to a 12 percent rise in rainfall. Sea levels are rising at rates consistent with global trends reported by the IPCC (Intergovernmental Panel on Climate Change), and projections indicate that temperatures could increase by more than 5°C by the end of the century under high-emission scenarios (UNDRR 2020). Additionally, the intensity of the summer monsoon and the likelihood of extreme rainfall events are also expected to rise significantly. As shown in Figure 2.2, projected changes in maximum five-day rainfall highlight that precipitation extremes are likely to intensify under RCP 8.5 scenarios, leading to an increased frequency of large-scale flooding across the country (World Bank 2021a).



Figure 2.2: Projected change in maximum 5-day rainfall (mm) over India for 2040–59 (left) and 2080–99 (right) under RCP 8.5, compared to the 1986–2005 baseline



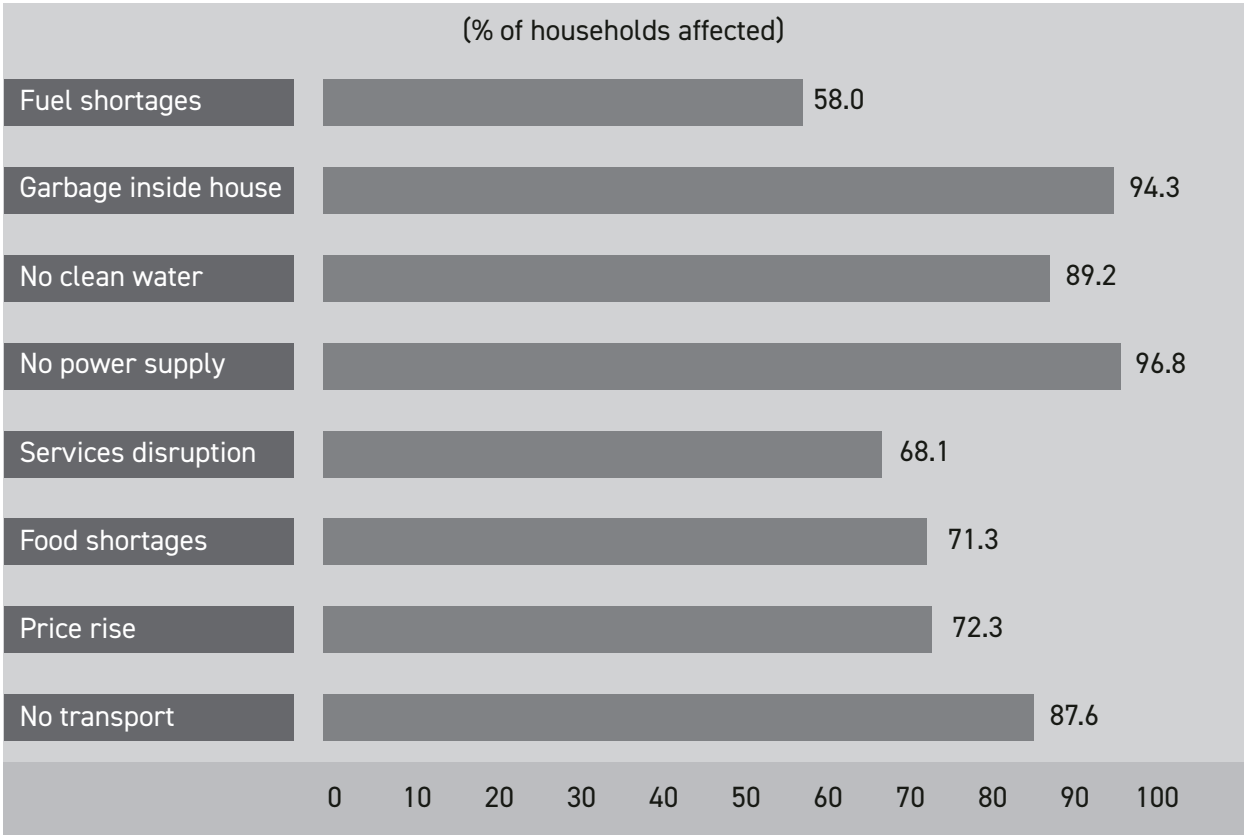
Source: World Bank (2021a)

The impacts of disasters in India are widespread and recurring, affecting all regions and sectors. Between 1991 and 2005, 431 major disasters resulted in an estimated 2 percent reduction in India's GDP. The 2004 Indian Ocean tsunami, although primarily affecting less industrialized regions, caused extensive livelihood losses for fishing and coastal communities and necessitated more than $300 million in recovery financing (IMF 2016). More recently, the 2018 Kerala floods and landslides affected over 5.4 million people, destroying homes, transport networks, and power infrastructure. Recovery needs were estimated at $4.4 billion, with infrastructure losses accounting for nearly 38 percent of the total. Additionally, Kerala's GDP contracted by 2.6 percent in the aftermath of these disasters (Government of Kerala 2018).

Major earthquakes, such as the 2001 Gujarat event, demonstrate the devastating social and fiscal toll of geological hazards. The earthquake, which measured 7.7 on the Richter scale, killed over 20,000 people, damaged nearly a million homes, and caused asset losses exceeding $2 billion (World Bank 2021b). Flooding, meanwhile, remains the most frequent and costly natural hazard; between 1980 and 2017, India experienced 278 major floods that affected more than 750 million people, causing about $58.7 billion in damages. Events such as the 2005 Mumbai floods—illustrated in Figure 2.3—underscore how extreme rainfall, combined with urban density and inadequate drainage systems, paralyse major cities. This creates a ripple effect of economic disruption that extends far beyond the areas directly impacted (ADB 2019).



Figure 2.2: Projected change in maximum 5-day rainfall (mm) over India for 2040–59 (left) and 2080–99 (right) under RCP 8.5, compared to the 1986–2005 baseline



Source: Author's calculation based on primary data.

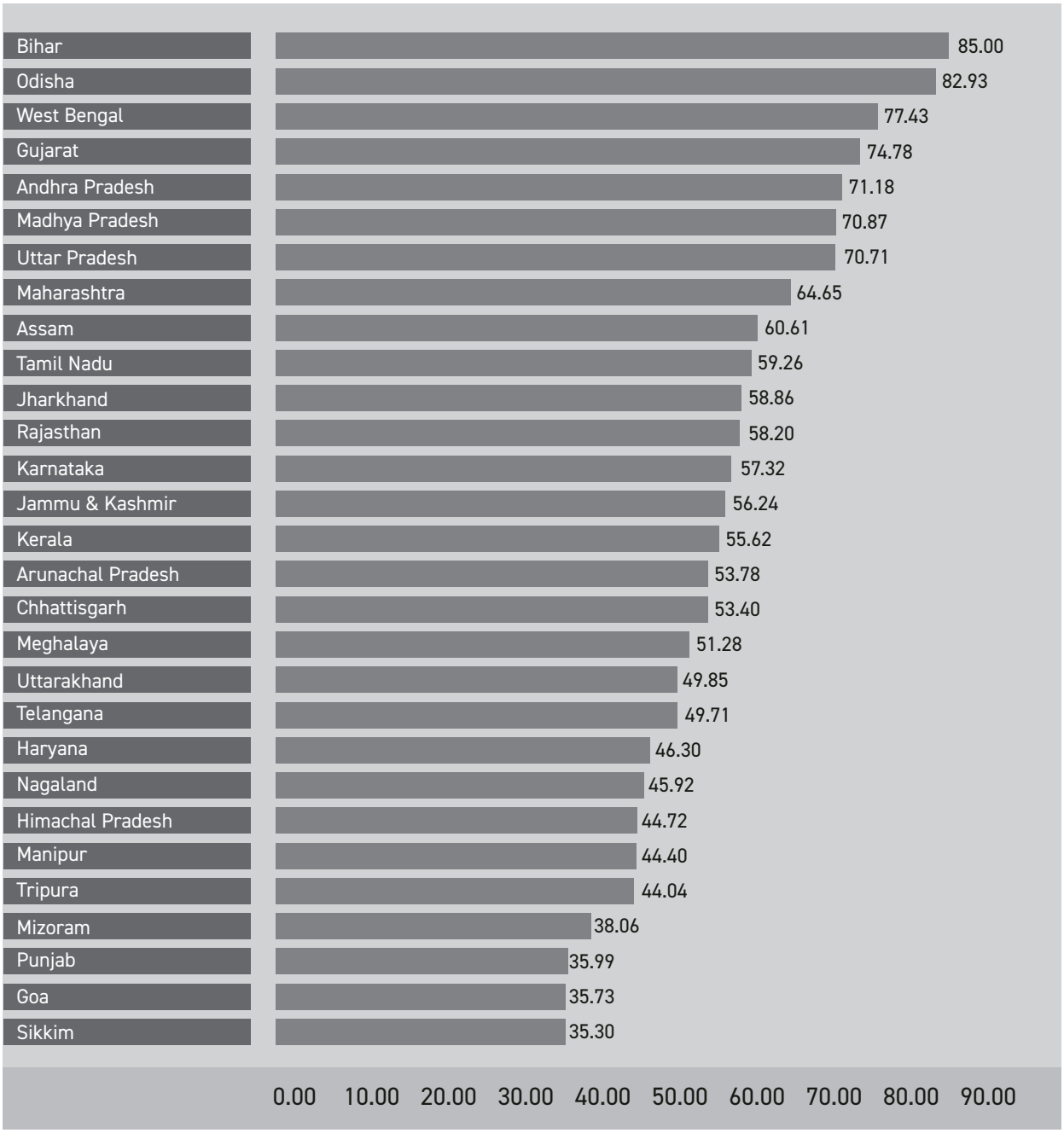
Cyclones and droughts continue to cause large-scale economic disruption. Roughly 10 percent of the world's tropical cyclones occur in the Bay of Bengal and the Arabian Sea, affecting India's extensive coastline. For example, Cyclone Fani in 2019 alone damaged over half a million houses and thousands of health facilities, with recovery expected to take several years (Roy 2019). Droughts are also a serious concern; about 68 percent of India's agricultural land is prone to drought. Severe meteorological droughts have affected large parts of the Indo-Gangetic plains and southern states in recent decades. The 2019 drought in Chennai, for instance, left reservoirs depleted, forcing 11 million people to rely on groundwater or tanker supplies (UNDP 2019).

Landslides and heatwaves further complicate India's risk profile. Landslides, particularly in the Himalayan and Western Ghats regions, cause recurrent damage to settlements and transport networks. These landslides are often triggered by deforestation and unregulated construction on unstable slopes. The 2013 Uttarakhand disaster, which resulted from heavy rainfall and glacier melt, claimed thousands of lives and displaced over 70,000 people (NIDM 2013). Heatwaves have also become a major hazard, with more than 15,000 recorded deaths between 2005 and 2017 (NIDM 2014). In response to these challenges, several Indian states have adopted early warning systems and local heat action plans to help mitigate health risks and productivity losses.



India faces a complex disaster landscape that has significant fiscal implications. Frequent disasters compel governments to reallocate planned investments towards relief and reconstruction efforts, thereby generating contingent liabilities that strain budgets at both the national and state levels. Figure 2.4 illustrates the state-wise hazard risk index, showing an uneven distribution of exposure and vulnerability across the country and highlighting areas where fiscal resilience needs urgent strengthening. Given that disasters now increasingly intersect with rapid urban expansion, climate change, and uneven adaptive capacities, their cumulative impact on public finance and long-term development is significant. Understanding these fiscal risks and integrating them into planning and budgeting processes is therefore essential to strengthen India's overall economic and infrastructural resilience.

Figure 2.4: State-wise hazard risk index (out of 100)



Source: Krishna S. Vatsa and Manasi A. Nanavati

Impact of Disasters on Power Infrastructure

India's power sector is among the largest in the world, yet its scale and diversity also make it highly exposed to disaster-related disruptions. The country's electricity system is organized into a three-tier structure comprising distribution networks, state grids, and regional grids. These are interconnected by high-voltage transmission lines, allowing power transfers between states. Despite significant expansion in recent years, there are still considerable regional disparities. As of 2021, per capita electricity consumption was approximately 1,200 kWh, significantly lower than the global average of approximately 2,800 kWh. Additionally, the reliability of supply varies across different states (Shukla and Thampy 2011). While near-universal access to electricity has been achieved, the sector continues to face challenges related to operational efficiency, cost recovery, and financial sustainability. High transmission and distribution losses, averaging 20–25 percent, remain a major issue. Furthermore, the tariff structures still rely on cross-subsidies to support household and agricultural users.

Electricity generation in India relies on a diversified mix of energy sources, including coal, hydropower, natural gas, renewable energy, and nuclear power. The composition of installed generation capacity, shown in Figure 2.5, highlights the ongoing dominance of thermal power alongside a growing share of renewable energy. There are significant regional supply imbalances, with the northern and eastern regions often experiencing shortages. In contrast, the western and southern states typically serve as net suppliers, supported by inter-regional transmission grids (as illustrated in Figure 2.6). These imbalances, combined with network congestion and aging infrastructure, increase the grid's vulnerability to disruptions during extreme weather events or peak-demand periods, such as prolonged heatwaves.

Figure 2.5: Sources of installed electricity generation in India, 2011 (MW)

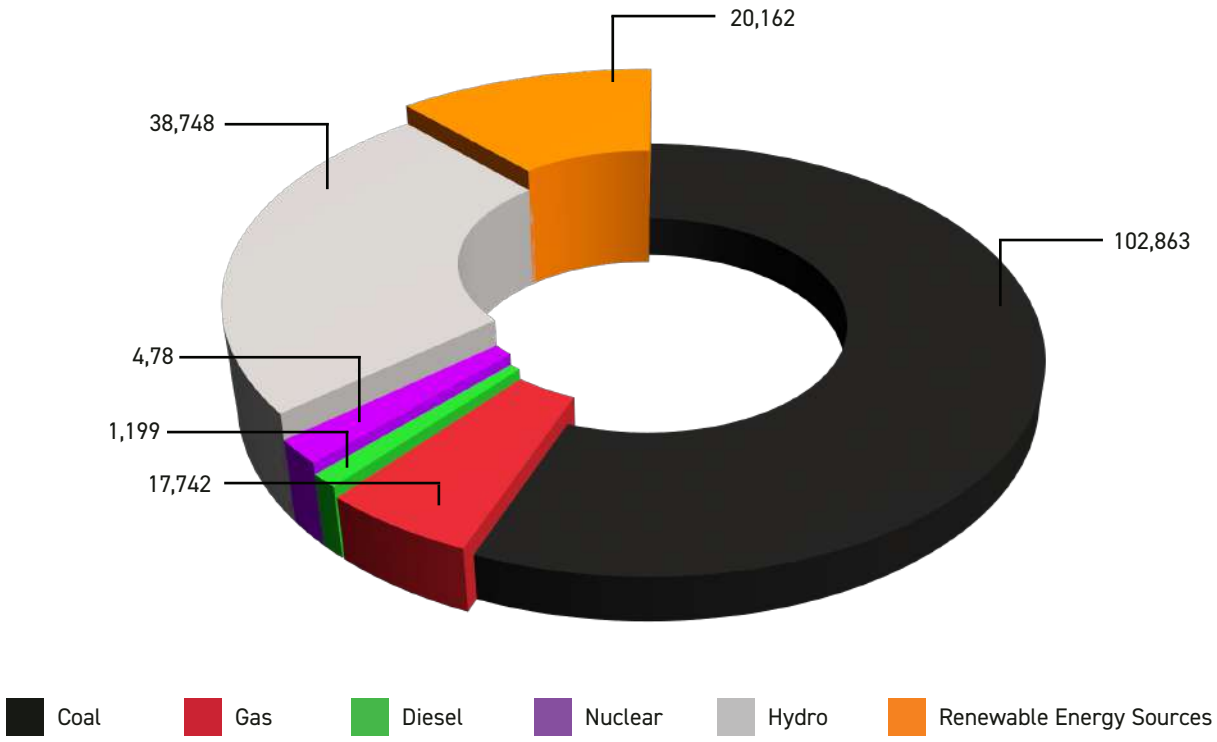
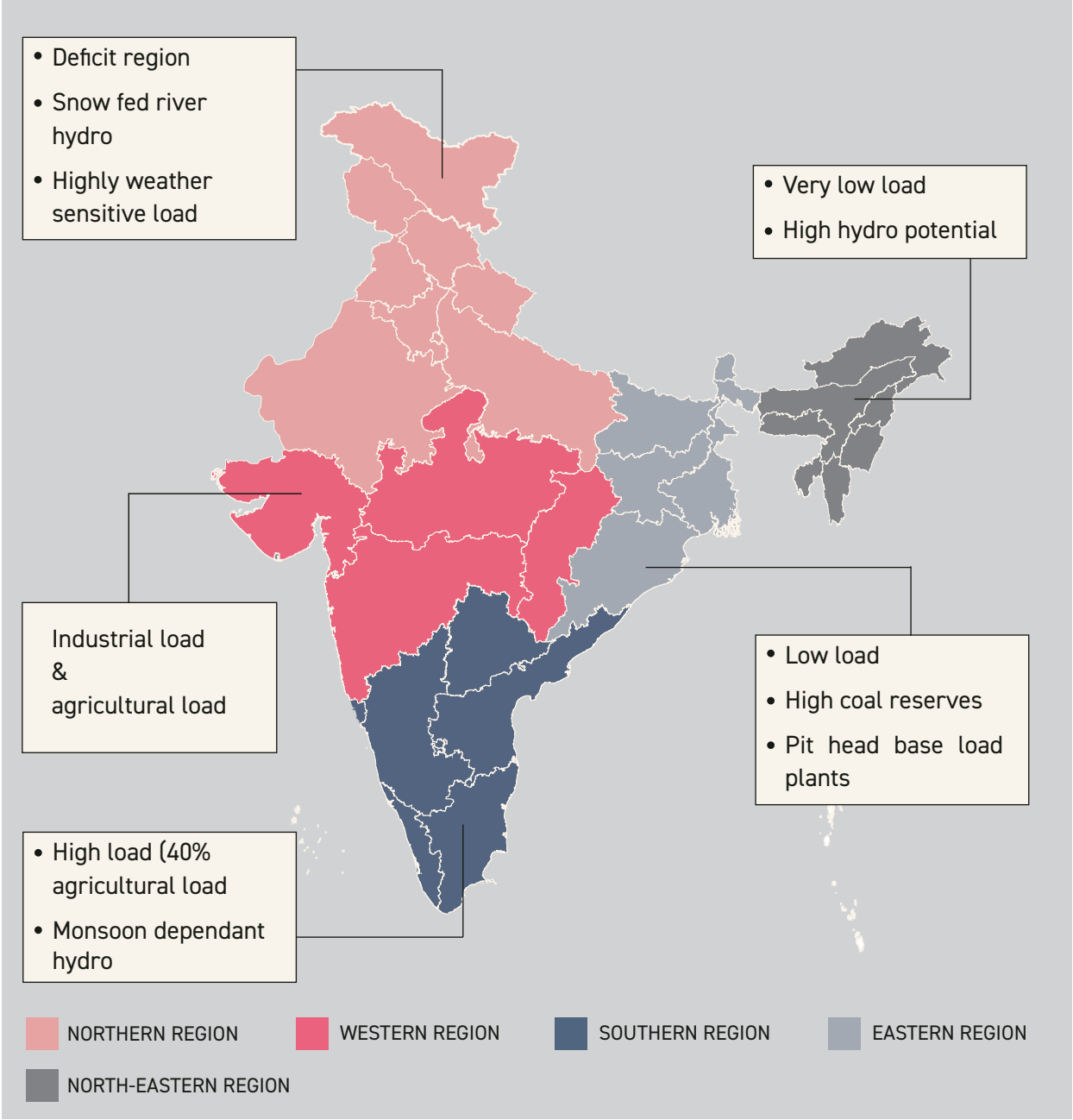


Figure 2.6: Supply and demand for electricity in India



Disasters have consistently impacted India's power sector, causing damage to transmission infrastructure, substations, and generation facilities. Flooding and cyclones, in particular, have repeatedly caused widespread power outages and costly restoration efforts. Cyclone Fani (2019), for instance, damaged more than 500,000 houses and severely disrupted electricity distribution in Odisha. The PDNA estimated that the direct damages to the power sector exceeded $150 million, which included the replacement of transmission towers, substations, and distribution assets (see Table 2.1) (Government of Odisha 2019). Similarly, the 2018 Kerala floods caused extensive damage to power infrastructure, with estimated recovery needs of approximately $200 million (refer to Table 2.2) (Government of Kerala 2018). These incidents demonstrate how disaster shocks can quickly create fiscal pressures for state utilities and governments, particularly where insurance coverage or contingency financing mechanisms remain limited.

Table 2.1: Damage estimates to power sector from Cyclone Fani

District	400 kV/ 220 kV and 132 kV (INR crore)	33 kV lines (INR crore)	33 kV/ 11 kV substations (INR crore)	Cost of 11 kV lines (INR crore)	11 kV/ 415 V DTR transformers (INR crore)	415 V lines (INR crore)	Total cost per district (INR crore)	Total cost per district ($ million)
Angul	93.5	1.7	0	5.6	0.5	39.2	47.1	6.7
Dhenkanal	-	4.4	0	8.3	0.5	30.2	43.4	6.2
Cuttack	-	71.1	1.6	165.7	57.3	104.8	400.5	57.2
Puri	-	61.2	4.8	356.2	169.3	51.5	643	91.9
Khurda	-	83.8	0.8	202.6	34.6	38.1	359.8	51.3
Nayagarh	-	9.4	0	13.2	1	11.6	35.1	5
Jagatsinghpur	-	43	17.6	286.6	106.1	239.3	692.6	98.9
Balasore	-	48.5	28.8	251.9	4.4	117.6	451.2	64.5
Bhadrak	-	60.7	20.8	195	8.4	143.9	428.8	61.3
Ganjam	-	237.3	48.8	1053.2	564.4	519.7	2423.5	346.2
Mayurbhanj	-	59.5	37.6	320.9	1.5	324.9	744.4	106.3
Jeypore	-	82.5	19.2	652.5	12.5	367.4	1132.1	162
Kendrapara	-	7.7	1.6	36.5	5	13.1	63.8	9.1
Keonjhar	-	77	28.8	419.9	0.9	51.5	578.1	82.6
Total (sans 400 / 220 kV and 132 kV)		847.6	210.4	3,968.10	966.2	2,052.90	8,045.20	1,149.30
Total (including 400 / 220 kV and 132 kV)			-	-	-	-	8,138.70	1,162.70

Source: Cyclone Fani PDNA

Table 2.2: Recovery estimates to power sector from Kerala floods

Activity	Typology for reconstruction/ recovery	Reconstruction/ Recovery (INR million)	Reconstruction/ recovery ($ million)
Generation	Civil works; Excitation system; Supervisory Control And Data Acquisition (SCADA); Control panel	808.50	11.6
Generation	Poles; Distribution transformers; Meters; Weatherproof cables; Earth Leakage Circuit Breakers (ELCBs).	2424.51	34.8
Generation	Power transformers; Conductors; Disc insulators; Circuit breakers; Lightning arrestors.	297.71	4.3
Total		**3530.72**	**50.7**

Source: Kerala Floods PDNA

The financial fragility of the electricity sector amplifies these risks. It is estimated that electricity shortages and outages cost the Indian economy up to 7 percent of GDP annually. Persistent technical losses, low-cost recovery, and delays in modernizing infrastructure limit utilities' ability to invest in resilient systems or to restore services rapidly post-disasters. State electricity utilities, which depend heavily on budgetary support, experience recurring liquidity stress following large-scale disasters, owing to the costs of emergency repairs and restoration efforts. Although institutional reforms and programmes such as the UDAY scheme have aimed to improve financial discipline and reduce distribution losses, climate and disaster risks continue to expose systemic weaknesses across the generation, transmission, and distribution sectors.

Recent PDNAs have begun systematically evaluating damages and losses in the power sector, thereby enhancing data-driven recovery planning. However, the documentation of these assessments remains inconsistent across states. Most loss estimates are recorded only for large-scale events, such as Cyclone Fani or the Kerala floods. Building a uniform national framework for reporting post-disaster damage in the power sector would enable more reliable fiscal risk assessments (FRA) and help prioritize investment. As disasters become more frequent and intense, incorporating resilience considerations into grid expansion, maintenance, and financing will be key for ensuring India's energy security and fiscal stability.

Impact of Disasters on Roads & Bridges

India's road network forms the backbone of its transport system and economic activity. Roads carry nearly 85 percent of passenger traffic and more than 60 percent of freight transport, making them critical to connectivity, trade, and livelihoods across the country. The national and state highway systems extend across diverse terrain, from flood-prone plains and coastal belts to landslide-susceptible mountain corridors, linking urban centres with agricultural and industrial regions. The Ministry of Road Transport and Highways (MoRTH) oversees national policy and highway development, while state public works departments and local authorities are responsible for the implementation and maintenance of these roads. Despite significant expansion, many stretches of India's 6.4 million-km road network remain narrow, congested, and in poor condition. Approximately one-third of rural villages still lack access to all-weather roads.

The sector's geographic spread and physical vulnerabilities make it highly vulnerable to natural hazards. Cyclones, floods, landslides, and extreme rainfall events routinely disrupt transportation and cause significant damage to pavements, bridges, culverts, and embankments. Flooding, in particular, leads to extensive scouring and washouts, while heavy monsoon rains accelerate the deterioration of pavements. In mountainous states such as Himachal Pradesh, Uttarakhand, and Sikkim, landslides often block highways and rural access routes, isolating communities for days. Along the coastal corridors of Odisha, Andhra Pradesh, and Tamil Nadu, cyclones generate high winds, storm surges, and saline intrusion, which weaken pavement structures and subsurface.

Recent disasters illustrate the scale of impacts. Cyclone Fani (2019) caused severe damage to road infrastructure across Odisha, uprooting trees, washing away embankments, and destroying culverts. The PDNA estimated the direct damages to the road sector at approximately $245 million (refer to Table 2.3). Similarly, the 2018 Kerala floods caused widespread flooding and landslides that destroyed or weakened more than 16,000 km of roads and over 300 bridges, with recovery needs estimated at $470 million (refer to Table 2.4). In both cases, the restoration efforts required extensive financial support from state and national governments, diverting resources from planned capital and maintenance budgets.



Table 2.3: Damage estimates to road sector from Cyclone Fani

	Road length affected (km)			Damage estimate	
Activity	SH (km)	MDR (km)	ODR (km)	Total (INR crore)	Total ($ million)
Angul	0	0	0	-	-
Balasore	50.69	62.58	214.21	6.8	0.97
Bhadrak	24.3	29.71	41.81	2.16	0.31
Cuttack	103.92	93.17	430.34	19.42	2.77
Dhenkanal	0	0	253.89	4.48	0.64
Ganjam	105.68	45.12	361.27	10.91	1.56
Jagatsinghpur	13.46	15.45	187.39	6.31	0.9
Jajpur	7.32	28.17	522.48	10.35	1.48
Kendrapara	30.16	22.45	259.55	9.18	1.31
Keonjhar	0	0	60.9	1.08	0.15
Khurda	33.69	206.71	746.33	28.89	4.13
Mayurbhanj	44.06	49.6	225.65	6.47	0.92
Nayagarh	44.66	66.41	290.11	7.98	1.14
Puri	71.38	115.83	382.35	17.44	2.49
Total	529.32	735	3,976.00	131.47	18.78



Table 2.4: Recovery estimates to road sector from Kerala floods

District	MDR (km)	SH (km)	INR million	$ million
Alappuzha	260.26	0.00	1,238.5	17.69
Ernakulam	780.85	71.43	3,554.5	50.78
Idukki	1,798.28	158.78	12,297.3	175.68
Kannur	126.75	45.92	1,115.7	15.94
Kasaragod	92.75	48.14	924.7	13.21
Kollam	285.05	8.30	1,801.8	25.74
Kottayam	571.97	65.63	2,588.6	36.98
Kozhikode	486.98	16.02	2,333.9	33.34
Malappuram	299.41	28.04	1,285.0	18.36
Palakkad	466.32	4.50	2,206.0	31.51
Pathanamthitta	227.17	8.20	5,771.7	82.45
Thiruvananthapuram	355.30	33.70	1,688.4	24.12
Thrissur	227.00	171.35	2,441.1	34.87
Wayanad	485.39	74.33	2,215.6	31.65
Total	6,463.48	734.33	41,462.7	592.32



These events underscore ongoing vulnerabilities within India's road sector. Inadequate drainage design, poor enforcement of right-of-way and land-use regulations, and limited routine maintenance exacerbate damage during extreme weather events. The recurring rehabilitation costs impose a fiscal burden on both central and state governments, as large portions of the road budget are reallocated to emergency works each year. Moreover, the lack of integration of climate and hazard data into road-design standards continues to limit long-term resilience.

As climate change intensifies the intensity and unpredictability of hydrometeorological events, it is crucial to strengthen the resilience of road assets. Improved asset inventories, geospatial risk mapping, and post-disaster loss tracking can help quantify contingent liabilities and guide the prioritization of resilient investments. Developing a uniform, data-driven framework for assessing road damages, similar to the PDNA methodology applied in Kerala and Odisha, will be key to reducing fiscal risks and ensuring reliable connectivity in a hazard-prone environment.

Fiscal Impact

India's fiscal landscape over the past five years has been influenced by multiple shocks, including the pandemic, inflationary pressures, and recurring disasters such as floods, cyclones, and heatwaves. These challenges have necessitated increased public expenditure on relief and recovery efforts, while limiting short-term revenue. As a result, the overall effect has been a widening of fiscal deficits and a rise in contingent liabilities at both the central and state levels.

Major disasters, such as the 2018 Kerala floods and Cyclone Fani (2019), underscored the magnitude of post-disaster financing needs. The recovery costs were estimated at $4.4 billion and were associated with extensive infrastructure losses. At the national level, fiscal pressures peaked in fiscal year 2020-21 when the government increased spending to support health, livelihoods, and infrastructure amidst weakened revenue collections. Since then, India has been working towards fiscal consolidation, gradually reducing the deficit and stabilizing public debt levels.

Revenue Trends

Government revenues have demonstrated resilience in the face of repeated shocks. According to the Controller General of Accounts (CGA), total revenue receipts reached INR 27.28 lakh crore in the financial year 2023-24. This amount includes INR 23.26 lakh crore in tax revenue and INR 4.02 lakh crore in non-tax receipts (CGA 2024). Tax collections rebounded strongly post-pandemic, supported by robust direct tax growth (nearly 19 percent in 2023-24) and improved compliance (PIB 2024).

The overall revenue-to-GDP ratio, which had dropped to 8.6 in 2020-21 during the pandemic, has since recovered to 9.2 in 2023-24 and is projected to reach 9.5 in 2024-25 (BE) (PRS Legislative Research 2024). Non-tax revenue has remained stable, driven by higher dividends from public-sector enterprises and the Reserve Bank of India.

At the sub-national level, however, states remain fiscally vulnerable to disaster shocks that reduce their own-source revenues from sectors such as tourism, transport, and property. This increased vulnerability reinforces their reliance on central government transfers and disaster-specific support from the National Disaster Response Fund (NDRF).

Public Debt Trajectory

Public debt rose sharply during the pandemic as the government borrowed to finance emergency spending and stimulus measures. The central government's debt-to-GDP ratio increased from 52.4 percent in 2019–20 to 59.3 percent in 2020–21, before moderating to 56.5 percent in 2023–24 (Ministry of Finance 2024a).

The Fiscal Responsibility and Budget Management (FRBM) statement projects a continued consolidation path, with the fiscal deficit targeted to decline from 5.6 percent of GDP in 2023-24 (RE) to 4.9 percent in 2024–25 (BE) (Ministry of Finance 2024b).

This trajectory indicates improved revenue growth and expenditure rationalization while maintaining capital investment in infrastructure and resilience-building. Maintaining medium-term fiscal sustainability remains a central priority, with the government aiming to gradually lower the debt ratio to pre-pandemic levels.

Fiscal Health Context

Although fiscal indicators are improving, recurring disasters continue to exert unplanned pressure on public finances. The central and state governments respond to these emergencies through the NDRF and state disaster response funds (SDRFs). Together, these funds received a corpus of INR 1.6 lakh crore for 2021–26. However, large-scale reconstruction—such as those following the 2018 Kerala floods or Cyclone Fani typically requires additional borrowing and reallocation from development budgets.

The Fifteenth Finance Commission (2021–26) has emphasized strengthening fiscal buffers, enhancing transparency in disaster-related expenditure, and integrating climate-risk assessments into budget planning. Moving forward, maintaining fiscal resilience will depend on several factors: expanding domestic revenue mobilization, improving expenditure efficiency, and adopting pre-arranged financial instruments to address the increasing costs associated with disasters and climate impacts.

Chapter 3

Institutional Frameworks and Provisions for Financing Post-Disaster Losses



Institutional Frameworks and Provisions for Financing Post-Disaster Losses

This section of the report reviews the different DRF plans and policies of the national and state governments. It focuses on funding mechanisms for post-disaster response and recovery measures. The goal is to understand the current DRF environment, including the specific mechanisms and processes in place, the hazards and assets or activities covered by the current national framework, and the available funding amounts. The section also provides a comprehensive review of existing budgetary allocations and government funding sources. Additionally, it includes a historical overview of disaster-related expenditures from both government and non-government sources.

Institutional Framework for Disaster Risk Management

India has established a robust and multi-tiered institutional framework for disaster risk management (DRM), anchored in the Disaster Management Act, 2005. This act marked a major shift from reactive relief to proactive risk reduction and resilience building. It provides a comprehensive legal and policy framework for disaster management at the national, state, and district levels, delineating clear roles, responsibilities, and financial mechanisms. Additionally, it mandates the creation of dedicated institutions for planning, coordination, and response, ensuring that disaster risk reduction is integrated into the country's development agenda.

National Framework and Key Institutions

At the national level, the Ministry of Home Affairs (MHA) serves as the nodal ministry for disaster management (except for droughts and epidemics). It operates through its Disaster Management Division (DMD). The National Disaster Management Authority (NDMA), chaired by the Prime Minister, is the apex policy-making body responsible for formulating policies, guidelines, and plans for disaster management. The NDMA oversees the implementation of the National Disaster Management Plan (NDMP), which aligns India's national priorities with the Sendai Framework for Disaster Risk Reduction (2015–2030) and integrates the Sustainable Development Goals (SDGs) and commitments under the Paris Agreement.

Supporting the NDMA, the National Executive Committee (NEC), chaired by the home secretary and including secretaries from key ministries, coordinates inter-ministerial actions, monitors policy implementation, and ensures compliance across sectors. The NIDM functions as the national knowledge and training hub, focusing on research, capacity building, and dissemination of best practices in DRM. The National Disaster Response Force (NDRF), established under the 2005 Act, provides operational response capabilities. The NDRF consists of 12 specialized battalions trained in search, rescue, and emergency response operations across multiple hazards.

Several scientific and technical agencies support this system by providing early warning, risk assessment, and hazard monitoring. The India Meteorological Department (IMD), the Indian National Centre for Ocean Information Services (INCOIS), and the National Centre for Medium Range Weather

Forecasting (NCMRWF) provide meteorological, oceanic, and tsunami forecasts. The Indian Space Research Organisation (ISRO), through its Disaster Management Support (DMS) programme, provides satellite-based data for hazard monitoring, damage assessment, and planning. These institutions work in concert to enable a science-based, technology-supported disaster management framework.

State and Local Structures

Under the Disaster Management Act, every state has established a State Disaster Management Authority (SDMA) chaired by the chief minister and supported by a State Executive Committee (SEC), which is led by the chief secretary. The primary responsibilities of the SDMA include preparing and implementing state disaster management plans, integrating mitigation and preparedness into sectoral policies, and ensuring interdepartmental coordination. At the district level, district disaster management authorities (DDMAs), headed by the district collector, serve as the first line of response and coordination, responsible for preparing and maintaining district-level disaster management plans, ensuring community preparedness, and disseminating early warning information.

This three-tier governance system provides coordination both vertically and horizontally among national, state, and local agencies. State and district authorities conduct regular mock drills, maintain emergency stockpiles, and coordinate local responses during disasters through state emergency operation centres (SEOCs) and district emergency operation centres (DEOCs).

Policy and Planning Instruments

India's National Disaster Management Plan (2019) serves as the core strategic document guiding all DRM efforts. The plan integrates risk reduction into national development by focusing on prevention, mitigation, and preparedness. It specifically addresses the needs of vulnerable groups, including women, children, persons with disabilities, and marginalized communities. Additionally, it provides a framework for managing specific hazards (such as earthquakes, floods, cyclones, droughts, and heatwaves). The plan also integrates key cross-cutting concerns, including climate change adaptation, ecosystem-based approaches, and social inclusion.

Complementary sectoral plans and mechanisms include the National Oil Spill Disaster Contingency Plan (NOS-DCP), managed by the Indian Coast Guard, which coordinates responses to hazardous and noxious substances. Additionally, the Building Materials and Technology Promotion Council (BMTPC) and Bureau of Indian Standards (BIS) collaborate to develop hazard-resistant construction standards and codes. Furthermore, academic and technical centres such as IIT Roorkee, IIT Kanpur, and IIT Delhi contribute to research, risk modelling, and early warning technologies.

Inclusion, Partnerships, and Private Sector Role

India's DRM framework explicitly integrates gender equity and social inclusion (GESI). The 2019 NDMP dedicates an entire chapter to gender and social inclusion, supported by NIDM's gender training modules and NDRF's efforts to enhance gender balance within its ranks. Together, these laws, policies, and institutions provide an integrated and multi-level framework for disaster management in India. This framework connects national policies with state and local implementation while promoting a whole-of-government approach to resilience.

Disaster Risk Financing Mechanisms in India



Historical Perspective of Disaster Risk Financing India's approach to disaster financing has significantly evolved over the past two decades. Prior to the enactment of the Disaster Management Act, 2005, the national approach was largely reactive. Relief expenditures were managed through ad hoc budget reallocations and emergency provisions, which offered limited predictability and no prearranged mechanisms for funding. Major disasters, such as the 1999 Odisha super cyclone and the 2001 Gujarat earthquake, exposed the limitations of this reactive model, particularly in ensuring timely and adequate fiscal response.

The Disaster Management Act, 2005, marked a decisive shift towards a structured and rules-based framework. It established a multi-tiered financing system with clearly delineated responsibilities at the national, state, and district levels. The act established the NDRF and SDRFs as dedicated funding sources for immediate relief and recovery operations. Additionally, it established mitigation funds to support long-term risk-reduction efforts.

Between 2013 and 2018, state governments collectively spent about INR 78,891 crore from their SDRFs and own resources, while the central government released an additional INR 36,726 crore through the NDRF. The combined expenditure, exceeding INR 1.16 lakh crore, illustrates both the scale of India's fiscal exposure to natural hazards and the centrality of these institutionalized funds in post-disaster response. Over time, partnerships with multilateral agencies such as the World Bank and the Asian Development Bank (ADB) have expanded, providing financing for major reconstruction programmes following significant disasters, including the Kerala floods (2018) and Cyclone Fani (2019).



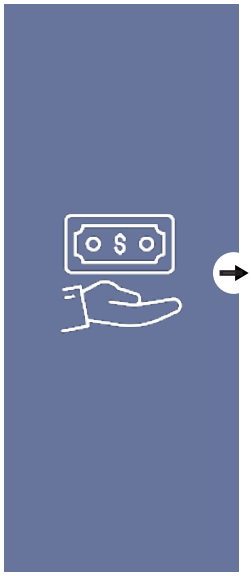
Current Disaster Risk Finance Mechanism The Ministry of Home Affairs (Disaster Management Division) serves as the central agency responsible for financing disaster response efforts. State governments implement relief and rehabilitation measures through their respective disaster management departments. Together, the NDRF and SDRFs form the foundation of India's current disaster financing system.

The SDRF, established under Section 48 of the Act, serves as the first line of fiscal defence for managing disasters at the subnational level. This fund is jointly financed by the centre and state governments, with a 75:25 funding ratio for general-category states and a 90:10 funding ratio for special-category states and union territories in the North-East and Himalayas. The resources from the SDRF are used to cover immediate relief expenditures, including search-and-rescue operations, temporary shelters, food, water, and agricultural input support. In addition, states may allocate up to 10 percent of the SDRF for locally declared disasters, even if those have not been formally notified by the central government.

The NDRF, constituted under Section 46, supplements state resources during severe disasters. The fund is completely financed by the central government, although it may receive grants or donations from other entities. Allocations are released based on state damage assessments reviewed by an inter-ministerial committee. Over the past decade, annual NDRF disbursements have varied significantly, reflecting variations in disaster frequency and scale.



***Ex Ante* Disaster Risk Financing Mechanisms** Considerable progress has been made in disaster management since the introduction of the Disaster Management Act 2005. India has established disaster management authorities at the national, state, and district levels, which are responsible for preparing and implementing disaster management plans. However, disaster risk financing remains centred on post-disaster relief and recovery through national- and state-level disaster response funds. Consequently, the government's Fifteenth Finance Commission has recommended four pre-disaster interventions: implementing disaster risk insurance, enhancing crop insurance, creating risk pools for infrastructure protection, and improving access to international reinsurance (UNDP 2024).



Reforms under the Fifteenth Finance Commission (XV-FC) The XV-FC (2021–26) introduced major fiscal innovations to strengthen pre-disaster financing. It recommended transforming the NDRF and SDRF into national and state disaster risk management funds (NDRMF and SDRMF). These new funds would have clear allocations: 80 percent for response efforts and 20 percent for mitigation measures. For the five-year period, the Commission allocated approximately INR 1.60 lakh crore to the SDRMFs and INR 68,463 crore to the NDRMF.

The funds allocated under the mitigation window are designed to support community-based risk reduction, enhance infrastructure resilience, and promote environmental restoration. The commission has also earmarked dedicated allocations for priority interventions, including fire services modernization (INR 5,000 crore), drought mitigation, erosion control, and urban flood management. These measures mark a shift from purely reactive spending towards risk-informed fiscal planning.



Sovereign Risk Transfer Instrument The experience with sovereign risk transfer instruments is currently limited to an index-based pilot project focused on excess rainfall that can cause severe flooding in Nagaland. The Nagaland SDMA, supported by the InsuResilience Solutions Fund, collaborated with the insurance sector to design a solution. However, at the national level, the XV-FC provided recommendations specific to disaster risk insurance and risk pooling. The NDMA and relevant line ministries are now addressing these recommendations.

Insurance

Public asset insurance falls under the responsibility of the relevant ministry or department. However, it is seldom utilized, and its overall penetration remains negligible. The UNDP diagnostic on inclusive insurance examines the status of various products available to the public, focusing on the following aspects:



Agriculture insurance:

India has a long history of government-subsidized crop insurance that dates back to 1985. In 2016, the Pradhan Mantri Fasal Bima Yojana (PMFBY) was launched, which includes the Restructured Weather-Based Crop Insurance Scheme (RWBCIS). PMFBY is now the third-largest crop insurance scheme in the world. Both schemes underwent reforms in 2020, with one of the biggest changes being the shift from mandatory to voluntary crop insurance.



Livestock insurance:

The government-supported livestock insurance scheme (LIS) was launched in 2005. Livestock insurance has significantly lower penetration compared to crop insurance. The product is offered by a limited set of insurance companies. LIS offers an indemnity product that covers death and permanent disability due to accidents, diseases, riots, strikes, etc., for up to 10 milk-producing 'cattle units'. The government subsidizes 85 percent of the premium share. Agriculture Insurance Company of India Limited (AIC) has launched an index-based insurance product to protect against deficits in cattle milk production caused by extreme heat.



Insurance for income protection/ business interruption:

Extreme Heat Income Replacement Insurance is a market-led index-based microinsurance product that was piloted in 2023. It provides compensation to women workers in the informal sector for income lost due to heatwaves.

Post-Disaster Financing Sources of the Country

National Disaster Response Fund

The NDRF, constituted under Section 46 of the Disaster Management Act, 2005, supplements the SDRF of a state, in cases of severe disasters when there are insufficient funds available in the SDRF. The entire contribution to the NDRF is made by the central government. To ensure an additional source of funding for the NDRF, the central government has established guidelines for receiving contributions or grants from individuals or institutions for disaster management. This is outlined in Section 46 (1) (b) of the Disaster Management Act, 2005, as an additional source of funding to NDRF. Refer to Table 3.1.

Table 3.1: NDRF and SDRF allocation (in million INR)

Year	Allocation under SDRF	$ (Million)	Centre's share of SDRF released	$ (Million)	Released from NDRF	$ (Million)
2019–20	134,650	1,548	109,370.625	1,257	185,305	2,130
2018–19	128,250	1,474	96,580.13	1,110	100,000	1,149
2017–18	122,140	1,404	93,820.8	1,078	47,225.3	543
2016–17	116,350	1,337	83,740.95	963	114,413	1,315
2015–16	110,810	1,274	87,560	1,006	124,519.6	1,431
2014–15	73,870.01	849	56,290.45	647	34,608.8	398
2013–14	70,350.23	809	60,340.08	694	46,499.4	534
2012–13	67,000.22	770	52,080.29	599	28,102.9	323
2011–12	63,810.18	733	42,790.45	492	24,589.2	283
2010–11	60,770.3	699	43,370.63	499	41,792.5	480

Source: Disaster Management Division, Ministry of Home Affairs, Government of India

State Disaster Response Funds

The SDRF was constituted under Section 48 (1) (a) of the Disaster Management Act, 2005. It is the primary fund available to state governments to respond to notified disasters. The central government contributes 75 percent of the SDRF allocation for general category states/union territories and 90 percent for special category states/union territories (which include the northeastern states, Sikkim, Uttarakhand, Himachal Pradesh, and Jammu and Kashmir). The annual central contribution is disbursed in two equal instalments, as recommended by the Finance Commission. The SDRF is intended solely for covering the immediate relief expenses for disaster victims. Disaster(s) covered under SDRF include cyclones, droughts, earthquakes, fires, floods, tsunamis, hailstorms, landslides, avalanches, cloudbursts, pest attacks, frost, and cold waves.

A state government may use up to 10 percent of the funds available under the SDRF to provide immediate relief to victims of disasters that they classify as 'disasters' within the local context. Such disasters must not be included in the notified list of disasters of the Ministry of Home Affairs. However, this is contingent upon the state government identifying state-specific natural hazards and notifying clear and transparent norms and guidelines for these disasters, with the approval of the state authority, i.e., the State Executive Authority (SEA).

Trend Analysis of Disaster Risk Financing in India

Analysis of fiscal data from the past decade indicates that India's disaster risk financing system has expanded steadily in scale, scope, and institutional maturity. Since 2010–11, combined allocations to the SDRF and NDRF have substantially increased. This growth reflects both the increased frequency and intensity of disasters and the government's commitment to integrate disaster response into fiscal policy.

Between 2010–11 and 2019–20, SDRF allocations rose from INR 60,770 million to INR 134,650 million, more than doubling in nominal terms (see Table 3.2). The centre's share of SDRF releases to states followed a similar trajectory, increasing from INR 43,370 million in 2010–11 to over INR 109,370 million in 2019–20. In contrast, allocations from the NDRF have fluctuated more sharply, reflecting the episodic nature of large-scale disasters. Disbursements surged from INR 41,793 million in 2010–11 to INR 185,305 million in 2019–20, with significant peaks in years marked by severe floods, cyclones, and droughts.



Table 3.2: Allocations and releases under SDRF and NDRF (2010–18)

Year	Allocation under SDRF (INR million)	Centre's share released (INR million)	NDRF releases (INR million)
2010–11	60,770	43,371	41,793
2012–13	67,000	52,080	28,103
2014–15	73,870	56,290	34,609
2015–16	110,810	87,560	124,520
2016–17	116,350	83,741	114,413
2017–18	122,140	93,821	47,225
2018–19	128,250	96,580	100,000
2019–20	134,650	109,371	185,305

Source: Ministry of Home Affairs, Disaster Management Division.

This data demonstrates both the growing fiscal footprint of disaster financing and its cyclical pattern. Years that experience major climatic shocks such as droughts or cyclones (e.g., 2015–16 and 2019–20) tend to exhibit spikes in NDRF disbursements. The consistent growth in SDRF allocations suggests improved predictability and planning at the state level. In contrast, the fluctuating NDRF figures reflect the contingent and event-driven nature of central assistance.

In addition to these allocations, the overall government expenditure on climate and geophysical calamities (refer to Table 3.3) underscores the macroeconomic scale of disaster-related fiscal activity. Annual spending on these increased from INR 327,385 million ($3.8 billion) in 2015–16 to nearly INR 2,885,853 million ($33.2 billion) in 2019–20. The exceptionally high expenditure recorded in 2018–19 (INR 3,721,248 million; $42.8 billion) corresponds with the severe flood and cyclone events of that year, which include major losses in Kerala, Odisha, and Andhra Pradesh.

Table 3.3: Government expenditure on account of Disasters (2015–20)

Year	Expenditure (INR million)	Expenditure ($ million)
2015–16	327,385	3,763
2016–17	279,988	3,218
2017–18	1,598,587	18,375
2018–19	3,721,248	42,773
2019–20	2,885,853	33,170

Source: EnviStats India, Ministry of Statistics and Programme Implementation (2020).

India's increasing allocations and expenditures for disaster response demonstrate a growing commitment to disaster-response financing, but this also exposes the country to greater fiscal risks. Disaster-related spending has become a significant component of subnational budgets, often requiring budgetary reallocation from development programmes.

At the same time, the introduction of mitigation funding under the Fifteenth Finance Commission (XV-FC) aims to stabilize this volatility over time by strengthening *ex ante* resilience investments. If implemented effectively, these provisions can reduce reliance on post-disaster borrowing and NDRF transfers.

Overall, the trend analysis reveals three key dynamics:

1. The scaling-up of institutional financing, including allocations from the SDRF and NDRF, has more than doubled over the past decade.
2. Persisting volatility in expenditure, tied to event severity and disaster cycles.
3. Additionally, there is a gradual reorientation towards risk reduction, as reflected in the XV-FC's creation of dedicated mitigation funds and earmarked resilience programmes.

While the architecture has matured substantially, long-term stability will depend on integrating risk analytics into fiscal planning, expanding the use of pre-arranged financing instruments, and improving transparency in the reporting of disaster-related outlays across all levels of government.

Chapter 4

Economic Modelling



Economic Modelling

To assess the economic implications of disasters in India, an econometric panel model was adopted. This approach was selected because it allowed consistent macroeconomic data from national and international sources, including the World Bank and International Monetary Fund (IMF). Compared with other modelling frameworks, such as input–output models, computable general equilibrium (CGE) models, or agent-based models, the panel approach was considered most feasible given the absence of detailed local or sectoral datasets.

Input–output and CGE models require granular data on inter-sectoral linkages, firm behaviour, and household-level consumption patterns. Unfortunately, such information is typically unavailable in the aftermath of disasters in India, where losses are typically localized and disaggregated data is scarce. Agent-based models were also excluded from this study because they require extensive micro-level data to simulate individual and institutional interactions, which were not available.

The panel model framework facilitates the analysis of fiscal and macroeconomic responses to disasters over time by integrating cross-sectional and time-series data. It quantifies the relationship between government fiscal indicators, such as expenditure, revenue, and debt, and a derived measure of disaster intensity, following approaches established in the literature on disaster economics (Noy 2016a; Panwar and Sen 2019). These fiscal variables are expressed as a percentage of GDP to enable comparisons across different periods and events.



A fixed-effects specification was used to capture both country-specific characteristics that remain constant over time and time effects that represent global or regional economic conditions. This methodology enables the isolation of the fiscal impacts of disasters while controlling for broader macroeconomic fluctuations.

All modelling was conducted in R, using the plm package, which offers robust tools for estimating fixed-effects models and testing hypotheses regarding individual and time effects. By examining pre- and post-disaster variations, the model identifies how disaster severity affects fiscal balances and public debt accumulation in India, compared to similar economies.

This econometric framework enables the analysis of indirect and long-term fiscal costs of disasters, which extend beyond immediate damage to infrastructure and livelihoods. By linking disaster intensity to fiscal performance, the model provides insights into how disasters shape expenditure priorities, debt dynamics, and revenue mobilization patterns, offering a quantitative basis for evaluating India's disaster risk financing and resilience strategies.

Economic Model and Data

This section outlines the datasets and variables used to develop the econometric panel model estimating the fiscal impacts of disasters in India. The model integrates fiscal data and disaster-related indicators from 2000 to 2019, supported by a standardized severity measure to capture disaster intensity.

Countries Included in the Model

Countries were selected based on their income classification, as previous research (IMF 2023) suggests that a country's income level affects the fiscal and economic consequences of disasters. India is classified as a middle-income economy; therefore, the panel model included all 69 middle-income countries to maintain consistency in economic structure and exposure.

Table 4.1: Summary of panel country sample (middle income; n = 69)

Component	Details
Country Group	69 middle-income countries
Basis of Inclusion	Income classification (IMF 2023)
India' Status	Middle-income; included in panel



Table 4.2: Middle-income countries included in the panel model (n = 69)

Albania	Georgia	Namibia
Angola	Ghana	Mauritius
Argentina	Guatemala	Nicaragua
Armenia	Honduras	North Macedonia
Azerbaijan	India	Pakistan
Bangladesh	Indonesia	Papua New Guinea
Belarus	Iran, Islamic Rep.	Paraguay
Bolivia	Iraq	Peru
Bosnia and Herzegovina	Jamaica	Philippines
Botswana	Jordan	Senegal
Brazil	Kazakhstan	Serbia
Cambodia	Kenya	South Africa
Cameroon	Kyrgyz Republic	Sri Lanka
China	Lao PDR	Tajikistan
Colombia	Lebanon	Tanzania
Congo, Rep.	Lesotho	Thailand
Costa Rica	Malaysia	Timor-Leste
Dominican Republic	Mauritius	Tunisia
Ecuador	Mexico	Ukraine
Egypt, Arab Rep.	Moldova	Uzbekistan
El Salvador	Mongolia	West Bank and Gaza
Eswatini	Morocco	Zambia
Gabon	Myanmar	Zimbabwe

Fiscal Variables and Sources

Fiscal data were obtained from the World Bank for the period 2000–2019, which provided the most comprehensive and comparable macro-fiscal indicators across the 69-country panel. The variables included the following:

Expense (% of GDP)	Revenue excluding grants (% of GDP)	Central government debt (% of GDP)

To ensure comparability over time, all fiscal indicators were adjusted for inflation using GDP in current US dollars. These percentage ratios were then converted into absolute values by multiplying each ratio by the corresponding annual GDP value.

During the preliminary analysis, autocorrelation year-to-year dependence between fiscal variables was identified. To address this, a first-order differencing method was applied. This process subtracts the previous year's value from the current year's value, thereby reducing serial correlation and isolating the short-term fiscal effects of disasters.

To avoid distortion caused by sharp GDP contractions during disaster years, GDP from the prior year was used as the denominator when calculating fiscal ratios. This ensured that extreme disaster-induced changes in output did not bias the relationship between fiscal indicators and disaster intensity.

Table 4.3: Fiscal variables and sources for India

Component	Details
Source	World Bank
Indicators	Expense (% GDP), revenue excl. grants (% GDP), central government debt (% GDP), GDP (current USD$)
Coverage	2000–2019
Processing	Converted to absolute values; first-order differencing applied to remove autocorrelation

The period from 2000 to 2019 was selected to maximize data continuity while avoiding distortion from the COVID-19 pandemic period. This dataset forms the basis for the fiscal component of the panel model used to assess disaster impacts.

Disaster Variables and Sources

Disaster data were sourced from the EM-DAT International Disaster Database, covering the same period (2000–2019). Only sudden-onset disasters—including floods, flood-induced landslides, and cyclones—were included in the analysis. Extremely rare or large-scale events such as earthquakes and tsunamis were excluded, as their exceptional magnitude could obscure relationships with more frequent, moderate disasters.

For each event, the following variables were extracted:

- Total number of fatalities
- Total population affected
- Total monetary damage

To ensure data completeness, quantile imputation was applied for missing values. Unlike mean or median imputation, which can bias results, quantile-based imputation preserves the statistical distribution and severity relationships across variables. For instance, missing data on 'population affected' were estimated using the quantile position of the corresponding 'fatalities' and 'monetary damage' variables. This approach ensures consistency in the representation of severity.

Table 4.4: Disaster variables and sources for India

Component	Details
Source	EM-DAT (International Disaster Database)
Indicators	Fatalities, Population affected, Monetary damages
Hazard Types	Cyclones, Floods, and flood-induced landslides
Coverage	2000–2019

Derived Disaster Intensity Measure: Life Years Lost (LYL)

To capture disaster severity in a standardized and comparable way, the life years lost (LYL) index was used, adapted from the World Health Organization (WHO)'s Disability-Adjusted Life Years (DALY) framework (Noy 2016a). The LYL combines three key dimensions of disaster impact—fatalities, population affected, and financial damages into a single measure of overall disaster intensity.

The LYL measure allows for direct comparison of disaster impacts across countries and hazard types. For India, the average annual LYL between 2000 and 2019 was approximately 4.8 million, with a standard deviation of 7.5 million. The most severe events were the 2007 Bihar floods (6.76 million LYL) and the 2004 Indian Ocean Tsunami (1.83 million LYL).

The LYL measure, together with total damages expressed as a percentage of GDP, constitutes the core explanatory variable in the econometric panel model. By linking this standardized disaster intensity indicator to fiscal outcomes, the model provides insights into how India's government expenditure, revenue, and debt evolve in response to disaster shocks.

Economic Modelling Results

This section presents the results of the econometric analysis undertaken to assess the fiscal impacts of disasters in India in the past two decades. The analysis used two measures of disaster intensity, LYL and total monetary damage (% of GDP), to estimate their relationship with key fiscal indicators: government expenditure (expense % of GDP) and central government debt (% of GDP).

A fixed-effects panel model with first-order differencing was employed to account for autocorrelation and unobserved heterogeneity. The model draws on national-level data for the period 2000–2019, sourced from the World Bank for fiscal indicators and EM-DAT for disaster data.

The LYL for the 2007 Bihar floods was 6,760,207, and for the 2004 Indian Ocean Tsunami it was 1,833,342. These values were used to calculate the potential effect on fiscal variables if an event of the same severity were to strike India again, based on 2019 fiscal values.

The econometric modelling found that disasters have a measurable and statistically significant impact on India's fiscal expenditure, but a comparatively smaller and statistically insignificant effect on central government debt.

Expenditure increases in response to both measures of disaster severity, confirming that fiscal resources are mobilized for relief, recovery, and reconstruction activities in the year of the disaster. Debt levels also rise, but the effects are not statistically significant, suggesting that much of the fiscal adjustment is achieved through budget reallocations, contingent funding, or external assistance rather than new borrowing.

The regression coefficients and associated significance levels for each fiscal variable under the two disaster measures are shown in Tables 4.5 and 4.6.

Table 4.5: Coefficients and significance (p value) for each fiscal variable included in the panel model for LYL

Fiscal Variable	LYL Coefficient	p Value	Standard Error
Source	0.00020488	0.5009	0.00030410
Central government debt, total (% of GDP)	0.00024839	0.04475*	0.00012358

* Significant at the 5 percent level.

Table 4.6: Coefficients and significance (p-value) for each fiscal variable included in the panel model for total damage (% of GDP)

Fiscal Variable	Total Damage (% of GDP) Coefficient	p Value	Standard Error
Central government debt, total (% of GDP)	0.00065033	0.3802	0.00074013
Expense (% of GDP)	0.00069540	0.02392*	0.00030737

* Significant at the 5 percent level.

In both models, government expenditure (% of GDP) shows a statistically significant positive response to disaster shocks, while central government debt (% of GDP) shows a positive but statistically insignificant relationship.



Modelled Fiscal Impacts

The model results were used to estimate the scale of fiscal impacts under three scenarios:

1. **Average disaster year,** based on mean annual LYL.
2. **Above-average disaster year,** corresponding to one standard deviation above the mean.
3. **High-severity disaster events,** based on historical cases such as the 2007 Bihar floods and the 2004 Indian Ocean Tsunami.

All monetary values are expressed in Indian Rupees (INR) using 2019 fiscal data as a reference.

Table 4.7: Modelled fiscal impacts of disasters in India (average-intensity events)

(Mean Annual Life Years Lost = 4,387,003)

Fiscal Variable	Average annual change due to disasters (% of fiscal variable)	95% confidence interval
Central government debt, (% of GDP)	0.14%	0.398%
Expense (% of GDP)	0.17%	0.162%

Fiscal Variable	Average annual change due to disasters (INR)	95% confidence interval
Central Government Debt	INR 230,282,586,261	INR 669,937,092,856
Expense (% of GDP)	INR 93,996,398,498	INR 91,660,319,883

In an average disaster year, **central government debt** increases by approximately INR 230 billion and **expenditure** by INR 94 billion.



Table 4.8: Modelled fiscal impacts of disasters in India (1 standard deviation above average severity)

(Life Years Lost ~ 7,521,599)

Fiscal Variable	Average annual change due to disasters (% of fiscal variable)	95% confidence interval
Central government debt (% of GDP)	0.14%	0.410%
Expense (% of GDP)	0.17%	0.167%

Fiscal Variable	Average annual change due to disasters (INR)	95% confidence interval
Central Government Debt	INR 236,887,785,361	INR 689,152,909,194
Expense (% of GDP)	INR 96,692,498,698	INR 94,289,414,302

In a year of above-average disaster severity, India's **fiscal expenditure** increases by approximately INR 97 billion, while **central government debt** rises by about INR 237 billion.

Table 4.9: Modelled fiscal impacts of high-severity disasters in India (selected historical events)

Event/Scenario	Fiscal variable	Change (% of fiscal variable)	Change (INR)	95% confidence interval
2007 Bihar Floods	Central government debt (% of GDP)	0.14%	INR 235,291,029,460	INR 684,507,633,909
2007 Bihar Floods	Expense (% of GDP)	0.17%	INR 96,040,737,284	INR 93,653,851,019
2004 Indian Ocean Tsunami	Central government debt (% of GDP)	0.13%	INR 215,767,736,272	INR 627,710,554,748
2004 Indian Ocean Tsunami	Expense (% of GDP)	0.16%	INR 88,071,748,937	INR 85,882,914,762

These results show that **severe disasters impose significant short-term fiscal pressures,** with expenditure increasing by up to INR 96 billion and debt by over INR 230 billion during major events.

Temporal Analysis

A dynamic panel model with one- and two-year lags of fiscal variables was estimated to assess the persistence of disaster impacts.

The results showed **no significant lagged effects,** indicating that the fiscal impact of disasters is **largely contemporaneous—**i.e., concentrated in the year of occurrence. Expenditure surges in response to disaster-related recovery and rehabilitation needs, but the effects taper off quickly thereafter.

Key Findings



Expenditure response

Disaster shocks lead to a statistically significant increase in government expenditure, highlighting the immediate fiscal burden of recovery.



Debt effects

Debt levels increase slightly but not significantly, suggesting that India's post-disaster fiscal adjustments rely less on borrowing and more on reallocation and external support.



Magnitude of Impacts

Severe events such as the Bihar floods and the 2004 tsunami result in expenditure increases equivalent to 0.1–0.2 percent of GDP.



Temporal concentration

Most impacts occur in the disaster year, with little persistence over subsequent years.



Policy implication

Strengthening *ex ante* financial instruments such as contingency funds and risk transfer mechanisms could help moderate these short-term expenditure surges. At the same time, investing in resilient and hazard-resistant critical infrastructure will reduce vulnerability and limit damages, thereby lowering the overall funding requirements for disaster response and reconstruction over the medium to long term.



Chapter 5

Probabilistic Assessment of Future Fiscal Risks through Catastrophe Modelling

Probabilistic Assessment of Future Fiscal Risks through Catastrophe Modelling

As climate change intensifies the frequency and severity of natural hazards, catastrophe modelling analysis helps us understand how return periods of these events evolve. This understanding is crucial to ensure that disaster risk management plans remain effective and aligned with current needs. By modelling potential costs before a major disaster occurs, we can better plan and prepare for such events. This includes analysing the breakdown of disaster-related losses, enabling a more tailored disaster risk finance strategy. This chapter presents the results of the catastrophe modelling used to assess the future impact of disasters on the power and road sectors, as well as their subsequent effects on the fiscal health of the state.



Hazard Model

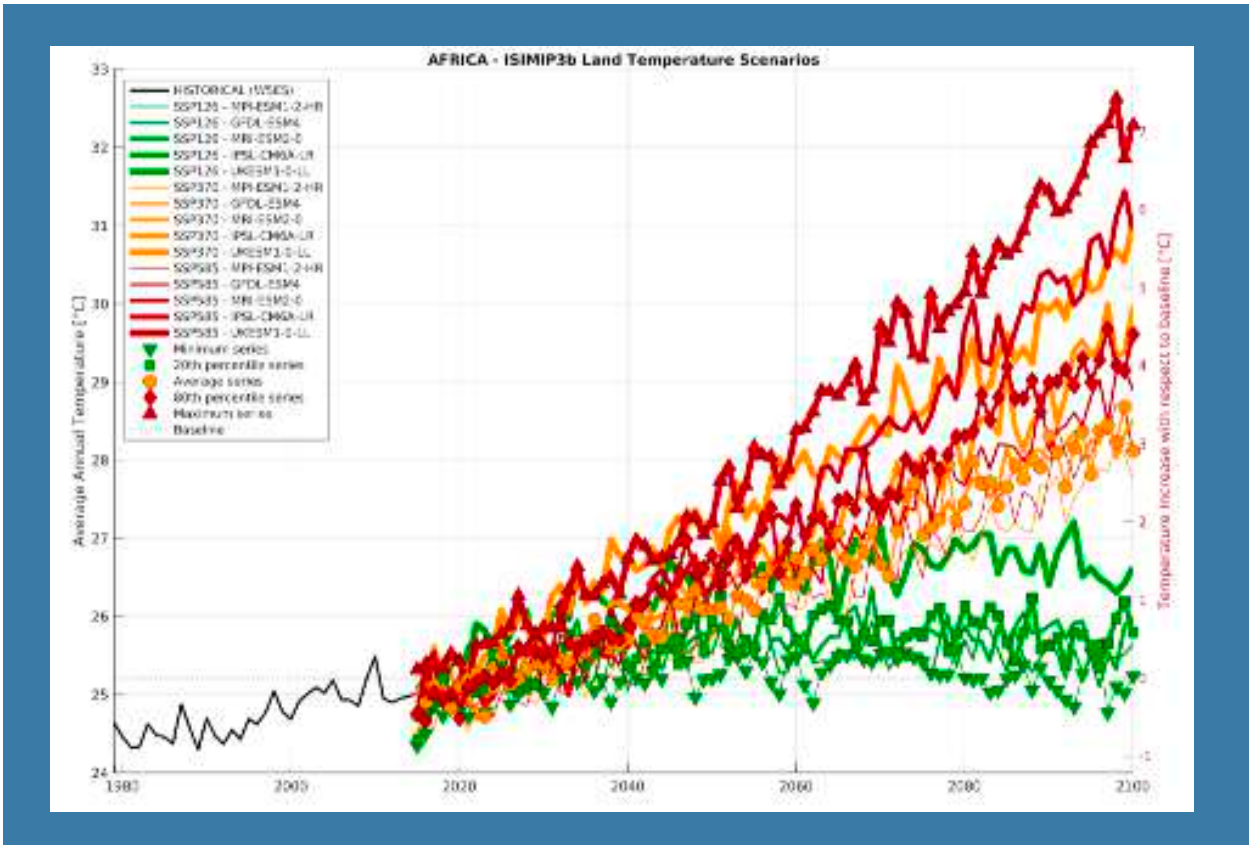
For the Fiscal Risk Assessment (FRA) of India, four key hazards are considered: earthquakes, tropical cyclones, floods, and landslides. These natural hazards are represented as a series of events. Each event denotes a specific occurrence of the hazard (e.g., a single tropical cyclone) and is characterized by its intensity at the location of the infrastructure elements and its probability of occurrence. The comprehensive set of events (i.e., all simulated tropical cyclones) represents the full range of how each hazard may occur. In the following sections, we will describe the different hazard models utilized in this assignment.

Climate Models

Model for Flood and Landslide Hazards

The climate models considered in this assignment are the same as those defined for the development of CDRI's Global Infrastructure Risk Model and Resilience Index (GIRI) (Cardona et. al. 2023). Multiple projections from Global Circulation Models included in CMIP6[2] were verified. These projections account for anthropogenic forcings represented by the combined SSP (Shared Socioeconomic Pathways) and RCP (Representative Concentration Pathways) scenarios, as defined by the IPCC (AR6). Figure 5.1 shows the spatial average of multiple future projections of surface temperature, up to 2100, obtained from the ISIMIP3b[3] database for Asia, compared to the average historical series obtained from the W5E5[4] dataset.

Figure 5.1: Average of future climate projections obtained from CMIP6 global circulation models



Cardona et al. (2023) selected the 20th and 80th percentiles of climate variation as indicative projections of lower and upper bounds. These percentiles correspond to projections provided by the IPSL-CM6A-LR model from the Institut Pierre-Simon Laplace, with a lower bound scenario SSP1-RCP2.6 and an upper bound scenario SSP5-RCP8.5.

[2] Climate Model Intercomparison Project version 6.

[3] Details available at https://www.isimip.org/gettingstarted/isimip3b-bias-adjustment/

[4] Details available at https://www.isimip.org/gettingstarted/input-data-bias-adjustment/details/114/

Hydrometeorological phenomena are modelled based on the meteorological conditions (such as precipitation and temperature) from a historical period, referred to as the 'Base climate'. This base climate corresponds to the years 1980 to 2010, which serve as the recent 30-year climate norm. Climate projections are then used to modify the Base climate using the Delta method, which alters the meteorological forcing in the Base climate, to match the 30-year average of a projected future climate. From this modified forcing, hydrometeorological hazards are recalculated.

Model for Tropical Cyclones Hazard

Cyclogenesis is a mesoscale process that requires high-resolution inputs from climate models. Therefore, not all climate models included in CMIP6 are suitable for cyclone hazard modelling. Only a few of the CMIP6 models have the necessary spatial resolution to project future cyclone tracks. These models are part of the PRIMAVERA High Resolution Project of CMIP6. For this assignment, we will be using four high-resolution[5] models: CMCC-CM2-VHR4,[6] CNRM-CM6-1-HR,[7] EC-Earth3P-HR,[8] and HadGEM3-GC31-HM.[9] These models consider only the emissions scenario SSP5-RCP8.5 for tropical cyclones. Consequently, the model is built on a single trajectory, rather than two bounds of climate variation, as is the case for other hydrometeorological hazards.

Flood Hazard Model

For the FRA of India, the global flood hazard model developed by Alfieri et al. (2023a) and Alfieri et al. (2023b) was used. This is the same model used by CDRI for the GIRI assessment (Cardona et. al. 2023). The model's spatial resolution is suitable for this assignment. In this section, we present a summary of the model; further details are provided in the original reference.

The model is based on the definition of inflows to the tributary basin upstream of various points along the main rivers and streams. It hydraulically simulates flow movement within the channels, accounting for inflows from sub-basins that contribute to the main channel basin. In this way, at an intermediate resolution, it is possible to cover all rivers in the country and determine flood areas and depths resulting from overflow.

To develop the global flood model from which the hazard assessment for India is extracted, a comprehensive global database of flows was compiled. This database gathers data from nearly 8,000 gauging stations worldwide, each with sufficiently long time series to enable a statistical analysis of extreme values. Although data were primarily collected daily, most of the available information was presented monthly. Therefore, stochastic techniques were employed to scale the time series to a daily format while preserving their statistical properties. This algorithm was calibrated using areas with daily time series accessible.

[5] In the context of climate modelling, high resolution refers to a spatial grid of 50 km in pixel size.

[6] Centro Euro-Mediterraneo sui Cambiamenti Climatici

[7] Centre National de Recherches Météorologiques. Meteo France.

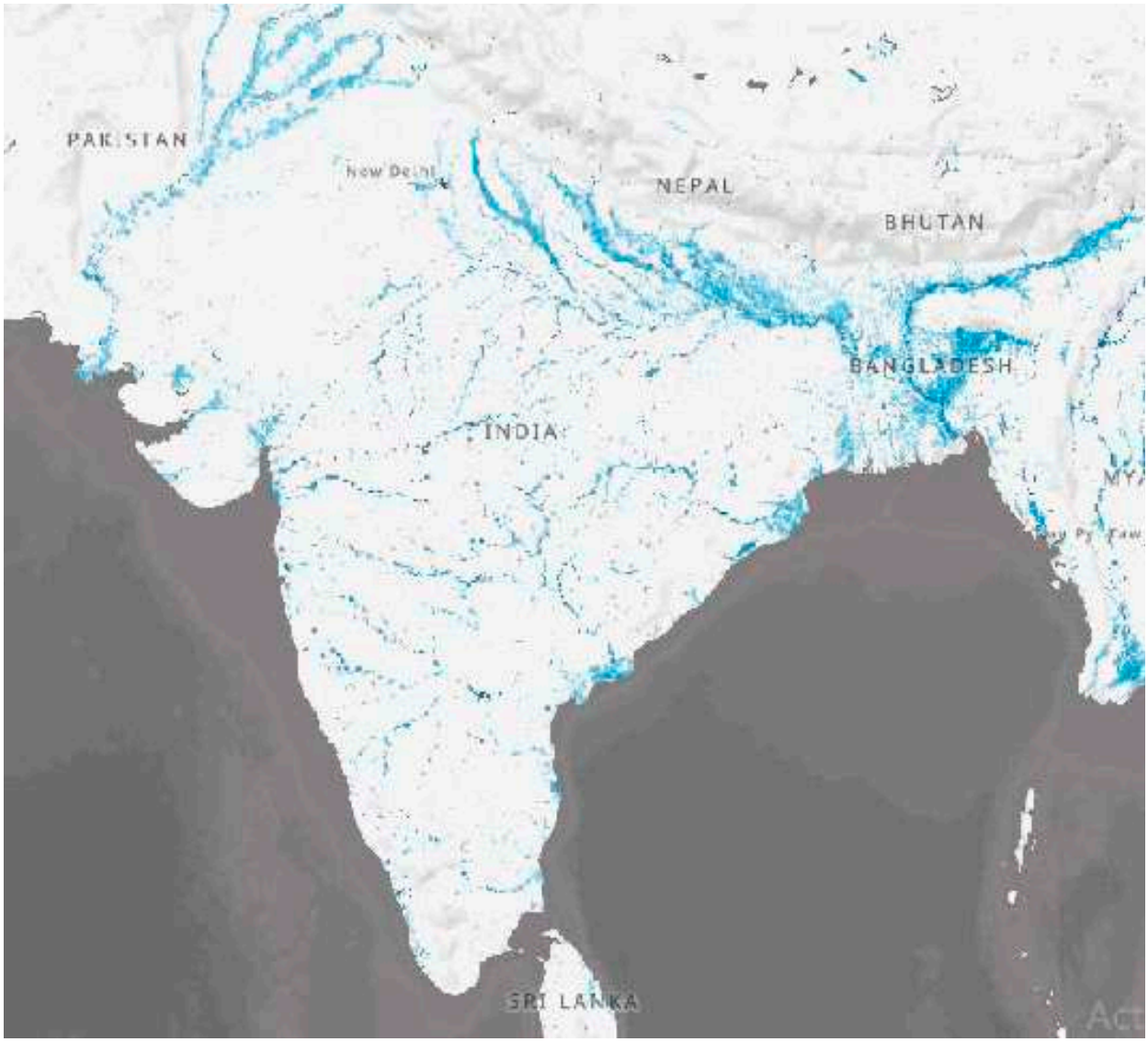
[8] Earth Consortium

[9] Hadley Centre Global Environment Model

Flood discharge magnitude is estimated using methods that rely on statistical analysis of data from the hydrological region. In this case, we implemented regional frequency analysis. The proposed methodology uses statistical data from a homogeneous region, identified using the index flood method (IFM), to estimate flood frequency at a specific site with the highest possible confidence, even for quantiles with very low frequencies. This approach increases the sample size by pooling time series from homogeneous groups, thereby forming a longer dimensionless time series. This helps reduce uncertainty in estimating outlier quantiles.

A continuous, distributed, physical hydrological model was used to improve regression analysis across climatic variables and to gain insight into areas where discharge rate cannot be determined from observations. Once discharge quantiles are obtained, these results are applied to the input data for a simplified hydraulic flood model. This model generates hydraulic cross-sections, with the flood stage calculated from flow values by solving the Manning equation. These flood stages are interpolated based on local relative morphology, and modifications are included to consider longitudinal hydraulic connectivity between sections, especially in large flood plains. Figure 5.2 presents the uniform flood hazard map for 100-year return period for India.

Figure 5.2: Flood hazard map for 100 years return period for present climate conditions in India

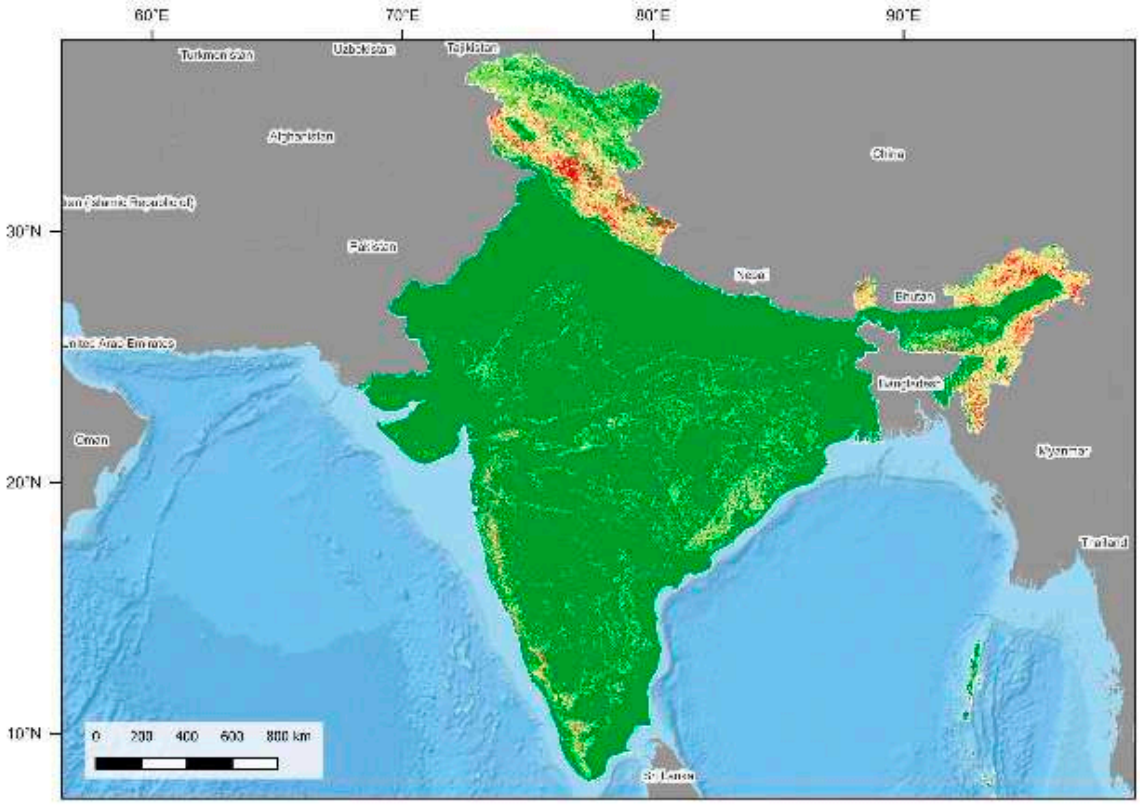


Landslide Hazard Model

For the FRA of India, the global susceptibility model and rainfall thresholds developed by Nadim et al. (2023) were used, along with the landslide hazard model developed by Cardona et. al. (2023). These model components were employed by CDRI for GIRI. The model's spatial resolution is suitable for this assignment. Here we present a short summary of the model.

The global susceptibility to landslides was established by Nadim et al. (2023). Susceptibility is modelled heuristically based on factors such as slope, lithology, vegetation cover, and soil moisture. Each of these characteristics is assigned a susceptibility factor (an integer number between 0 and 5) and weighted by its expected impact on landslide susceptibility. The result is the weighted sum of the contributing characteristics at each mountainous location within the region. Local modifiers, such as population density or road density, are also included to account for the anthropogenic influence on landslides. The susceptibility is mapped at a spatial resolution of 30 m, with values ranging from 0 to 5. More information about the model is provided in Nadim et al. (2023). Figure 5.3 shows the landslide susceptibility map for India.

Figure 5.3: Landslide susceptibility of India



Source: Nadim et al. (2023)

Landslide hazard depends not only on susceptibility but also on triggering factors—external forces that can locally increase instability and trigger a landslide. In this assignment, such factors are excess rainfall and seismic acceleration. The rainfall trigger is obtained directly from the climate modelling (see Section 3.1.1.1) while the earthquake trigger is simulated using the seismic hazard model (see Section 3.1.5). Nonetheless, landslide thresholds are required to set the corresponding triggering intensity. In this assignment, we have used the thresholds proposed by Nadim et al. (2023), presented in Tables 5.1 and 5.2.

Table 5.1: Rainfall threshold for landslide hazard

Range of P_n	Susceptibility				
	Susc. 1	Susc. 2	Susc. 3	Susc. 4	Susc. 5
$P_n < 0.3$	0%	0%	0%	0%	0%
$0.3 \leq P_n < 2.0$	0%	1%	2%	3%	5%
$2.0 \leq P_n < 3.7$	0%	2%	3%	5%	10%
$3.7 \leq P_n < 5.0$	0%	3%	5%	10%	15%
$P_n > 5.0$	0%	5%	10%	15%	20%

Source: Nadim et al. (2023)

Table 5.2: Seismic acceleration threshold for landslide hazard

Range of PGA	Susceptibility				
	Susc. 1	Susc. 2	Susc. 3	Susc. 4	Susc. 5
$0.05 \leq \mathrm{PGA} < 0.15$	0%	0%	0%	0%	0%
$0.15 \leq \mathrm{PGA} < 0.25$	0%	0%	0.1%	0.5%	1%
$0.25 \leq \mathrm{PGA} < 0.35$	0%	0.1%	0.5%	1%	5%
$0.35 \leq \mathrm{PGA} < 0.45$	0%	0.5%	1%	5%	10%
$\mathrm{PGA} \geq 0.45$	0%	1%	5%	10%	40%

Source: Nadim et al. (2023)

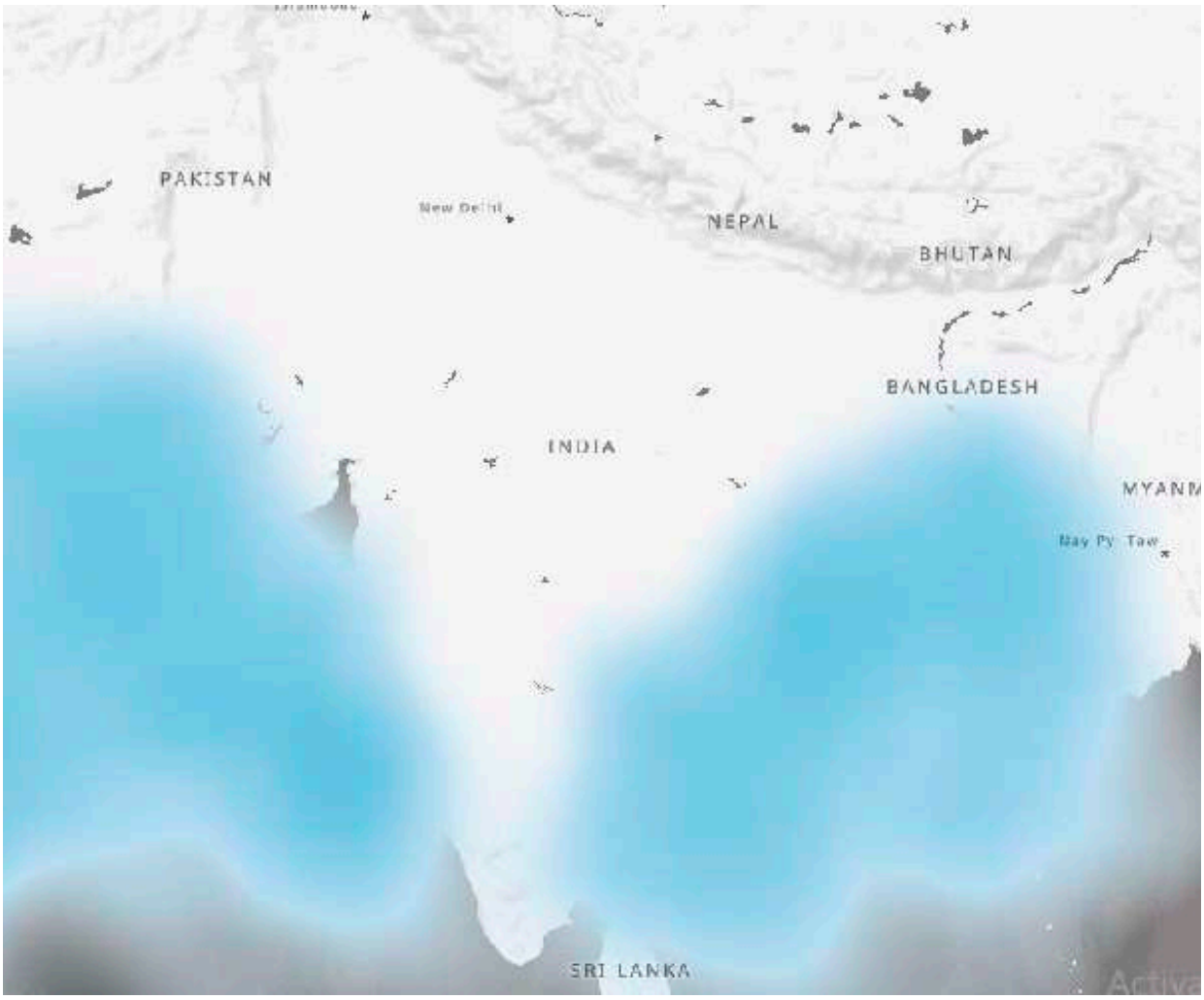
Based on the susceptibility and thresholds, the model estimates the probability of a landslide for simulated triggering rainfall or seismic acceleration. It should be noted that landslides are treated as events with very high local energy, for which reason the vulnerability of any exposed element is saturated, thus causing a total loss. Therefore, vulnerability functions for this phenomenon have not been developed.

Tropical Cyclones Hazard Model

For this assignment, the tropical cyclone hazard was updated, including the latest cyclone trajectories up to 2024. The calculation method is the same as that used by Cardona et al. (2023) for CDRI's GIRI and Cardona et al. (2014) for the GAR Global Risk Model by the United Nations Office for Disaster Risk Reduction (UNDRR). The method is implemented in the CAPRA ROBOT software module TCHM (Bernal 2013). Detailed information on the methodology is provided in Cardona et al. (2014).

The hazard from both strong winds and storm surge was assessed for this project using an updated catalogue including 155 historical tropical cyclones for the North Indian Ocean basin. Completeness periods were recalculated to determine the occurrence frequency of historical cyclones. For each historical track, a family of associated 'children' tracks was obtained using a bi-dimensional Wiener process. Strong winds, speed, and storm surge flooding were calculated for each cyclone child track, and the results were used to compute probability moments of wind speed and coastal flood for each historical track. The results are expressed, for the strong winds, in terms of the geographical distribution of the peak wind speed of 3-s gusts, and for the storm surge, as the distribution along the shorelines of the maximum surge run-up and its associated flooding. This analysis was repeated for all historical and future cyclone tracks. The hazard assessment results comprise probabilistic wind fields and storm-surge flood hazard maps. Figure 5.4 shows the map of the 500-year return period of strong winds for India.

Figure 5.4: Cyclone wind hazard for India with a 500-year return period (intensity in km/h)



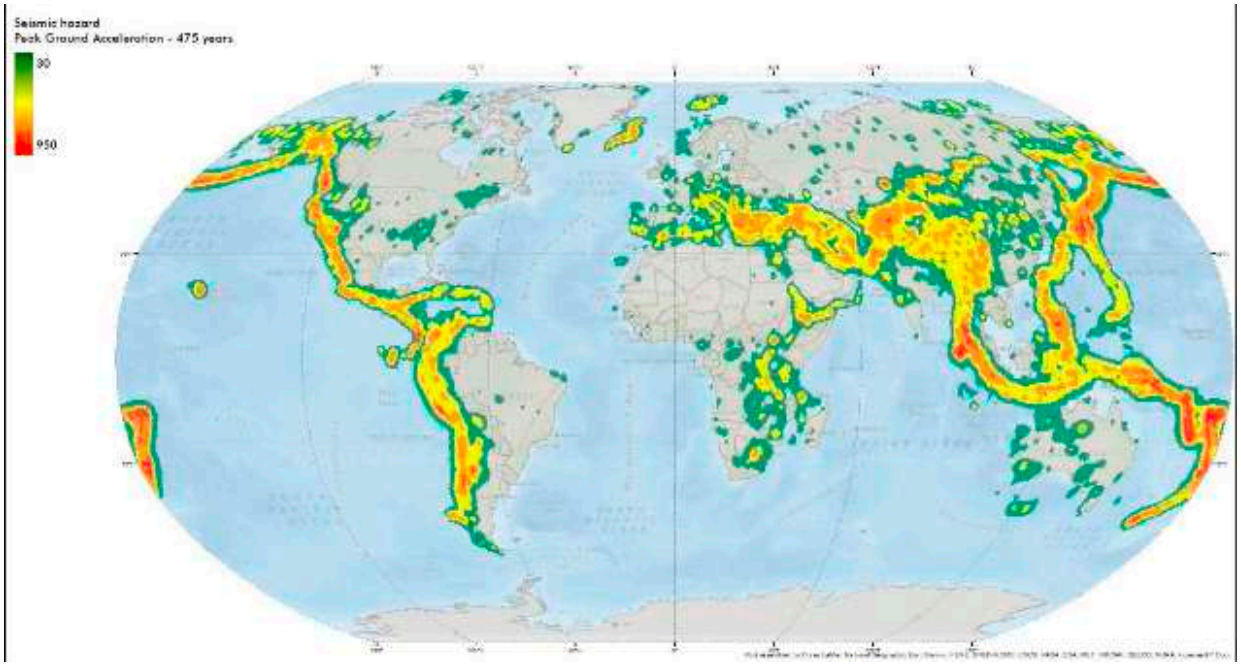
Seismic Hazard Model

Seismic hazard has no relation to climate and is, therefore, considered stationary. For the FRA of India, the global seismic hazard model developed by Cardona et al. (2014) was employed. This is the same model used for CDRI's GIRI assessment (Cardona et al. 2023) and for the GAR15 Global Risk Model. The

model's spatial resolution is appropriate for this assignment. This section presents a general overview of the model.

The seismic hazard at the bedrock level is calculated using historical data from seismic catalogues. Given each earthquake's magnitude and hypocentre location, the event intensity is calculated using a set of mutually exclusive, collectively exhaustive stochastic scenarios, each with a geographic probability distribution. This is carried out considering the attenuation of seismic energy with distance around each event's strike zone. This evaluation thus provides a curve showing the probability of exceeding the acceleration at a point where certain exposed assets may be subjected to it. Given that the said curve is obtained for each one of the points within the calculation grid, it is possible to calculate the seismic hazard maps for various spectral ordinates and return periods. In other words, according to the characteristics of the dynamic structural response from the exposed structures. This input is fundamental for the probabilistic risk assessment on the inventory of exposed elements conducted in countries with seismic hazards. An in-depth description of the seismic hazard model can be found in Cardona et. al. (2014). Figure 5.5 shows an example of a seismic hazard map calculated for a 475-year return period of the peak ground acceleration at bedrock level (i.e., Vs30 = 1100 m/s).

Figure 5.5: Seismic hazard map for peak ground acceleration and 475-year return period



Exposure Model

The database of exposed elements is defined as the collection of physical elements that constitute an infrastructure system, for which three properties are established as a minimum: its geographic location, its physical value or replacement cost, and a constructive or archetypal class that allows its vulnerability to be related. It is common that some, or even all, of the three fundamental characteristics are not available in the information that exists within the country, which is why it is necessary to make estimates that represent or account for said inventory of exposed elements in an approximate way. India's exposure in this assignment is limited to the power and roads sectors.

Power Sector

In this assignment, the power sector refers to the existing infrastructure for the generation, transmission, and distribution of electricity within the territory. Oil and gas infrastructure, which some authors consider part of the power sector, is excluded. The power sector is therefore subdivided into three subsectors: Generation, Transmission, and Distribution. Each subsector requires an independent exposure model that accounts for the unique characteristics of its elements. For example, elements in the Generation subsector are typically power plants that vary widely in the types of energy they convert, plant capacity, and facility components. On the other hand, transmission lines, although diverse as well, are far more constrained in terms of the number of typologies to be considered. This makes the power sector one of the most complex to model in a risk assessment.

Power Generation in India is highly diverse. According to data from WRI (World Resources Institute) and OSM (Open Street Map). There are more than 2 million MW of installed generation capacity, distributed across eight types of energy conversion, as shown in Table 5.3. Regarding Transmission, there are more than 400,000 km of transmission lines in India and more than 600 major substations. Table 5.4 shows the total length of transmission lines of different operational voltages.

Table 5.3: Installed capacity of the generation sector in India

Source energy	Capacity [MW]	[-]
Bioenergy (biomass, waste, etc.)	1,244	0.1%
Coal	295,823	12.5%
Gas	29,937	1.3%
Hydro	71,074	3.0%
Nuclear	10,785	0.5%
Oil (petroleum derivatives)	3,609	0.2%
Other	10,688	0.4%
Solar (photovoltaic)	47,689	2.0%
Wind	1,904,517	80.2%
Total general	**2,375,367**	

Table 5.4: Transmission line voltages and lengths in India

Voltage (kV)	Length	[-]
<110	28,345	6.7%
110 - <220	132,255	31.2%
220 o >220	263,872	62.2%
Total	**424,473**	

The procedure for defining the replacement cost of power sector components is the one proposed by Cardona et al. (2023) and used to value exposed elements in the GIRI model by CDRI.

Generation

The replacement cost estimate for the exposed elements in the Generation subsector is based on data from the Global Power Plant Database (WRI) and the Power Plant Database (OSM). It is worth noting that no official information was received during the execution of this assignment. The procedure for estimating the cost of generation infrastructure is described next.

First, the raw data is cleaned by removing records that lack information on the energy source or generation capacity. Then, the data on energy sources are reclassified into one of the basic classes listed in Table 5.5. Next, the capacity of each plant is verified within the existing information. If there is no data on plant capacity, it is randomly assigned from a probability distribution of capacities of the same type of energy source (see Cardona et al. 2023 for further details). Finally, the replacement cost is calculated by multiplying the cost indicators from Cardona et al. (2023), as defined by IRENA, by the plant capacity.



Table 5.5: Basic Energy Source Classes and Unitary Costs

Source energy	Cost indicator ($/kW)
Bioenergy (biomass, waste, etc.)	2,353
Battery (storage)	758
Coal	875
Gas	1,116
Geothermal	3,991
Hydro	2,135
Nuclear	3,782
Oil (petroleum derivatives)	795
Solar (photovoltaic)	857
Wave and tidal	7,038
Wind	1,325
Other	1,134

Source: Cardona et al. (2023)

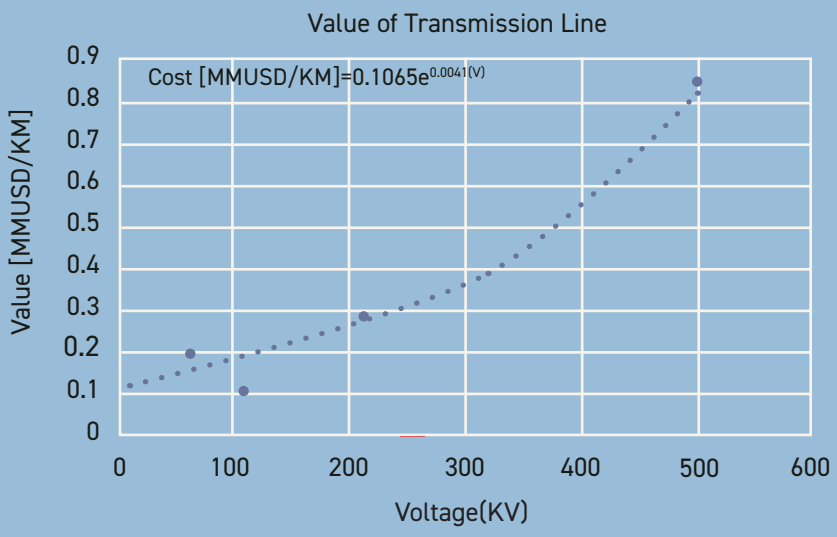


Transmission

For the Transmission subsector, raw data are obtained from the OSM Power Lines Database and Power Substations Database. No official information was received during the execution of this assignment. The procedure for estimating the cost of transmission infrastructure is described next.

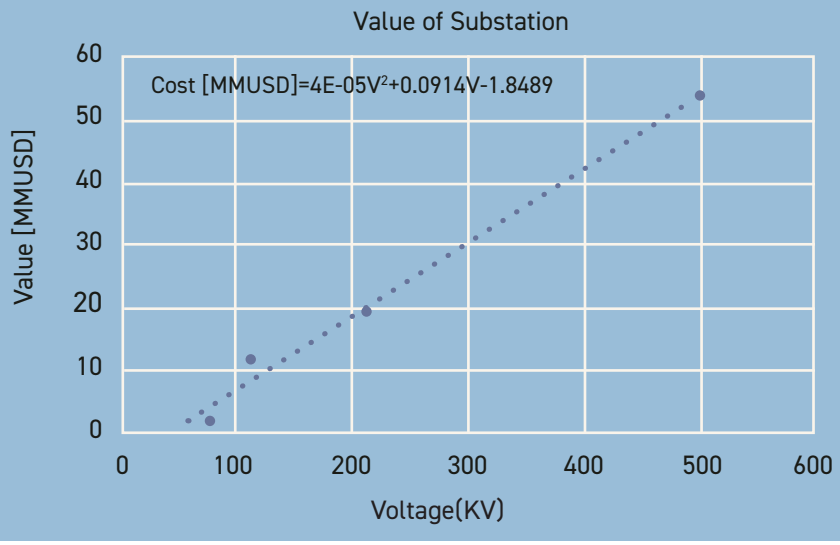
For the transmission lines, first, the length of each element is determined from the raw spatial data. Long elements are trimmed into segments of 150 m or less. Then, the line voltage is used to determine the cost indicator, according to the price function proposed by Cardona et al. (2023), as shown in Figure 5.6. Finally, the segment's overall cost is calculated by multiplying the corresponding cost indicator by its length.

Figure 5.6: Pricing function (based on transmission line voltage)



For substations, the raw data is first cleaned to remove substation elements that do not correspond to transmission or distribution networks. Finally, the cost is evaluated based on the working substation voltage using the pricing function proposed by Cardona et al. (2023), as shown in Figure 5.7.

Figure 5.7: Pricing function (based on voltage at substation)



Distribution

Distribution networks are highly correlated with population density. They are commonly denser where the populations are more concentrated, and vice versa. Furthermore, data on the actual locations and characteristics of distribution network elements (such as cable posts, buried lines, and transformers) are unavailable. It is important to note that no official information was received during the execution of this assignment. Therefore, we will apply the framework developed by Cardona et al. (2023) to develop a population-based exposure proxy for the distribution network.

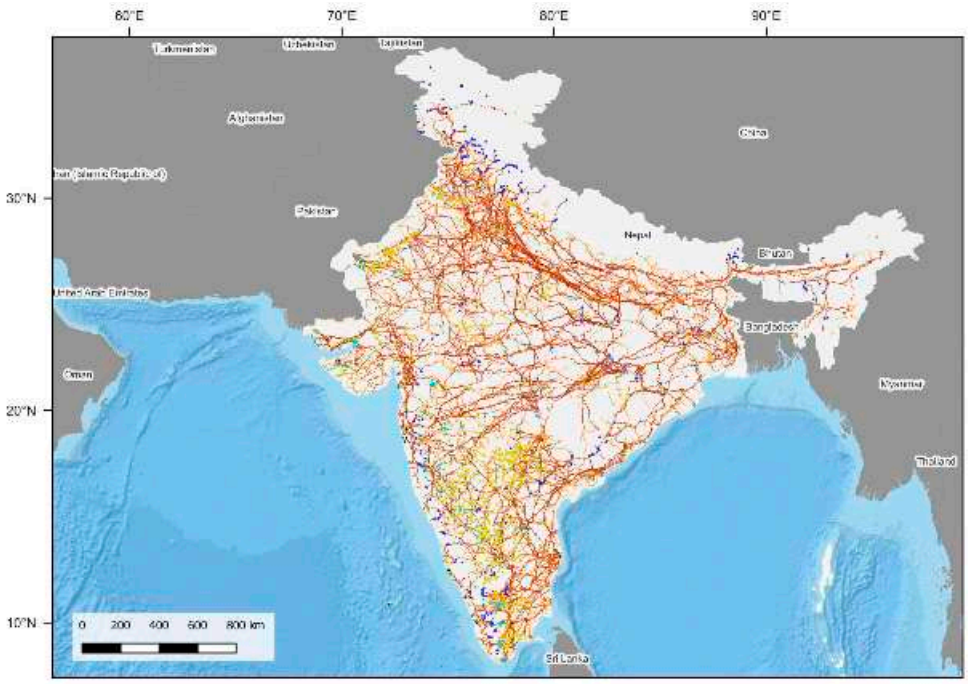
Cardona et al. (2023) propose valuing the distribution subsector as a factor of the transmission subsector[10]. This approach yields a comprehensive valuation that must be distributed geographically using the GHSL population raster grid.[11] This population grid is then adjusted to reflect the percentage of the population with access to electricity; for India, this figure is 99.2 percent of the total population according to World Bank data.[12]

This procedure yields higher exposure values in denser populations and a bulk infrastructure value consistent with actual access to electricity.

Exposure Database

The resulting exposure model comprises geolocated vector entities with attributes useful for risk evaluation. The replacement cost and the archetype of each element are key f ields for characterizing exposure. Figure 5.8 shows a general overview of the sector in India.

Figure 5.8: Exposure database for power sector in India



[10] The factor is 2.26. See Cardona et al. (2023) for further details.

[11] Global Human Settlements Layer. Details available at https://human-settlement.emergency.copernicus.eu/ghs_pop.php

[12] Details available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS

Road Sector

The road sector in this assignment encompasses highway infrastructure, including expressways, national highways, state highways, and major district roads and bridges. Road infrastructure varies based on design conditions, including topography, weather, and traffic. Furthermore, highway segments consist of multiple elements, including pavement structure, retaining walls, gutters, and box culverts. A similar situation occurs with bridges, where each is distinct from the others. Although they can be classified into archetypal categories, bridges are among the few infrastructure elements that avoid typification. In addition, the available data has strong limitations. Note that no official data was received during the execution of this assignment. Therefore, the e exposure model generated is only a good-enough approximation of the sector for risk assessment purposes.

According to the OSM dataset, in India, there are approximately 400,000 km of roads, covering only expressways, national highways, state highways, and major district roads. In addition, there are 7,000 km of bridges within the same road types. Minor district or rural roads, as well as private roads and bridges, are not included in this assignment.

Road Segments

The procedure for defining the replacement cost of road sector components is the one proposed by Cardona et al. (2023) and used to assign value to exposed elements in CDRI's GIRI model. In this procedure, the Global Roads Network dataset from OSM is processed to remove erroneous or incomplete records. The roads are segmented to a maximum length of 300 m to increase model granularity. The basic value of each segment is calculated from its length using a nominal cost of $1.09 million per km.

The segment's basic value is approximated based on four main features: road type, number of lanes, pavement type, and slope. Each feature implies a multiplication factor that modifies the basic value of the segment.

Road type refers to the operational level of a road within a country's road network. It is an important modifier that accounts for variations in replacement cost based on the road's overall importance. The corresponding multiplication factor is presented in Table 5.6.

Table 5.6: Road type multiplier

Road type	Factor
National highways	1.50
State highways	1.00
Major district roads	0.83
Other roads	0.67

Source: Cardona et al. (2023)

The number of lanes indicates the level of demand the road segment can accommodate. We use the factor proposed by Cardona et al. (2023), which is calculated as half the number of lanes in the segment. Therefore, a 2-lane road is considered the basic condition with a multiplication factor of 1. Roads with more lanes increase the exposure value beyond the basic replacement cost.

Pavement type also affects the segment cost. It is evident that replacing a segment of paved road would be more costly than replacing a segment of affirmed gravel. We use the factors proposed by Cardona et al. (2023) and group them into three categories: paved, affirmed, and loose. The factors are presented in Table 5.7.

Table 5.7: Pavement type multiplier

Pavement type	Factor
Paved	1.00
Affirmed	0.34
Loose	0.18

Source: Cardona et al. (2023)

Finally, slope significantly affects the cost of replacing road segments. Replacing a road segment with similar characteristics on steep terrain is much more expensive than doing so on flat terrain. Furthermore, certain critical elements, such as retaining walls, are far more likely to be present in steep terrain compared to flat terrain, where they typically do not exist. We use the slope factors proposed by Cardona et al. (2023), which are presented in Table 5.8.

Table 5.8: Slope Multiplier

Slope type	Slope angle	Factor
Plain	0-10	1.00
Rolling	10-15	1.43
Hilly/Mountainous	15-25	1.82
Steep	>25	2.16

Source: Cardona et al. (2023)

Bridges and Tunnels

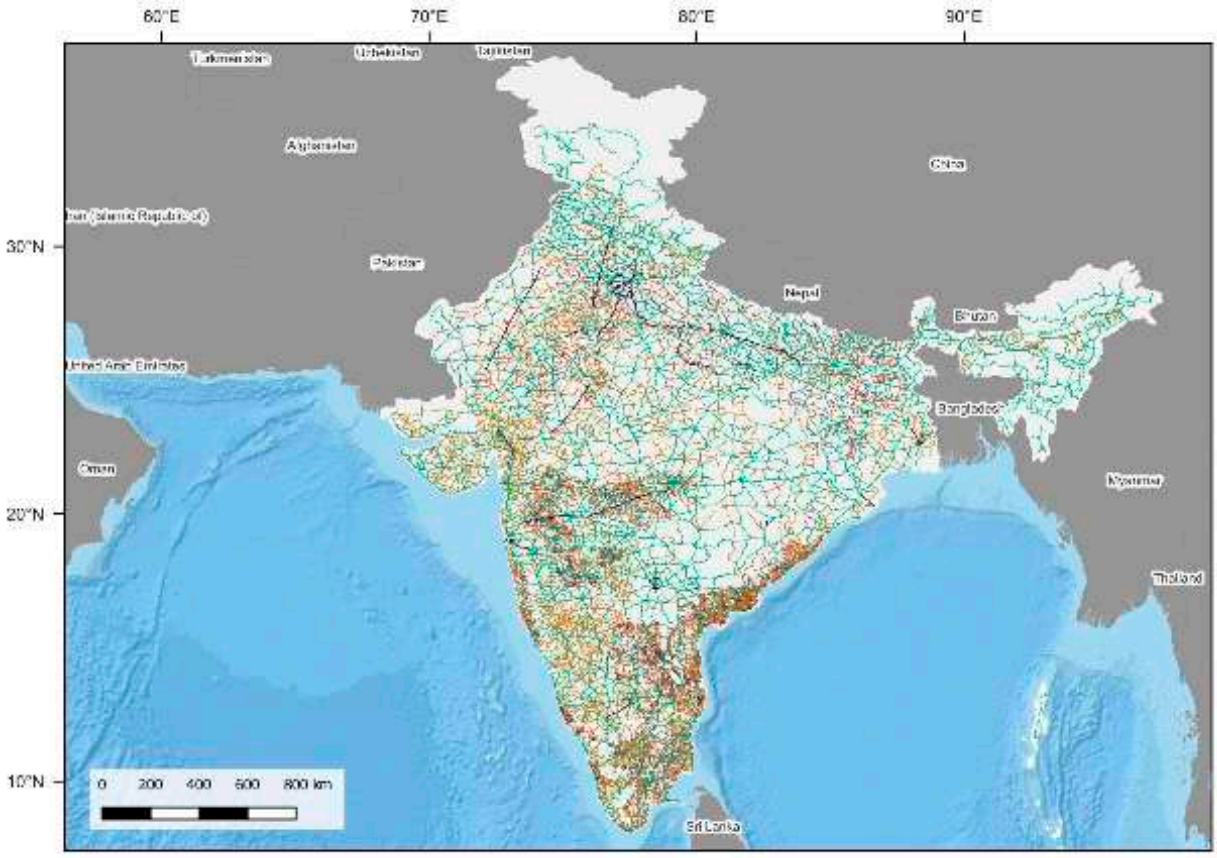
Bridges are infrastructure elements that are particularly difficult to typify. It could be said, with high confidence, that there are as many types of bridges as there are bridges in the world. This, of course, complicates any attempt to classify bridges. However, given the current state of the data, such a classification attempt is not feasible because the available information is insufficient to distinguish among structural differences in existing bridges. Key properties of the bridge, including span, gauge, support type, number of pillars, abutments, foundation, and board structure, among many others, remain unknown. The available data from the OSM dataset only provides information on the bridge length. We use this length to estimate the replacement cost, based on the cost indicator proposed by Cardona et al. (2023), which is $9.84 million per km.

Finally, tunnels are included. They share some of the difficulties highlighted for bridges, including the impossibility of reliable generalization and the lack of detailed information. Nonetheless, for each identified tunnel in the OSM dataset, the exposed value is estimated using the average price indicator proposed by Cardona et al. (2023), which is $ 19.8 million per km.

Exposure Database

The resulting exposure model comprises geolocated vector entities with attributes useful for risk evaluation. The replacement cost and the archetype of each element are key fields for characterizing exposure. Figure 5.9 gives a general overview of the sector for India.

Figure 5.9: Exposure database for road sector in India



Vulnerability Models

The physical vulnerability of exposed elements can be modelled using vulnerability functions that capture the complexity of loss generation when the elements are subjected to a hazardous event. Additionally, vulnerability functions quantify loss probabilistically, thereby enabling the application of the conceptual framework to risk assessment.

Probability Model for the Loss

In catastrophic risk modelling, losses are treated as random variables. This allows the uncertainty inherent in loss amounts from any hazard to be directly accounted for in the calculations. Vulnerability is defined for each element within the exposure portfolio, indicating that the loss here pertains to a single exposed element. In general, loss is a value between 0 and 1 (0–100 percent of the exposed value of the element) (e.g., the replacement value of a property or infrastructure element). This means that, from now on and in general when discussing vulnerability, the loss always corresponds to a relative loss, measured by the degree of damage; that is, it is a fraction of the exposed value.

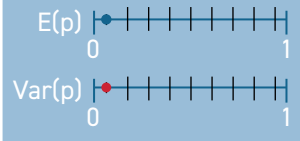
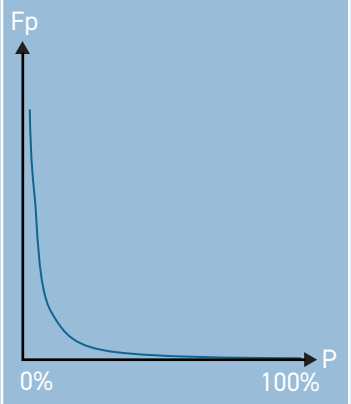
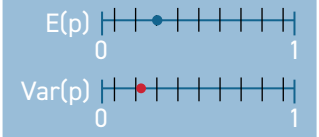
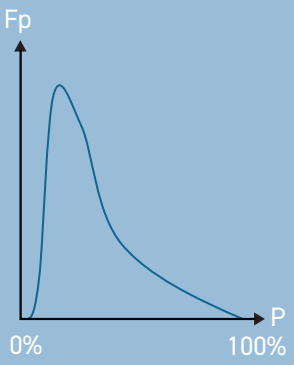
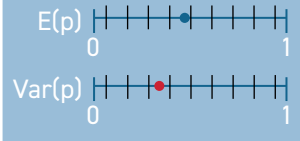
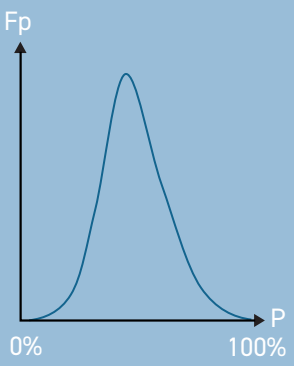
In general, there is not enough information on the damage and losses caused by historical events to adjust a probability model based on statistical estimates. Therefore, defining a probability model that describes the randomness of loss is a decision that, while reasonable and appropriate, is ultimately arbitrary. The most widely used model is a Beta distribution, proposed by Anne Kiremidjian and other authors in developing the ATC-13 document and its commentary, ATC-13-1 (ATC, 1985, 2002), which aimed to define probability models for earthquake damage in California. Since then, the use of the Beta distribution as a probability model for loss has been adopted globally for all types of hazards and exposed elements. This model is practical for several reasons:

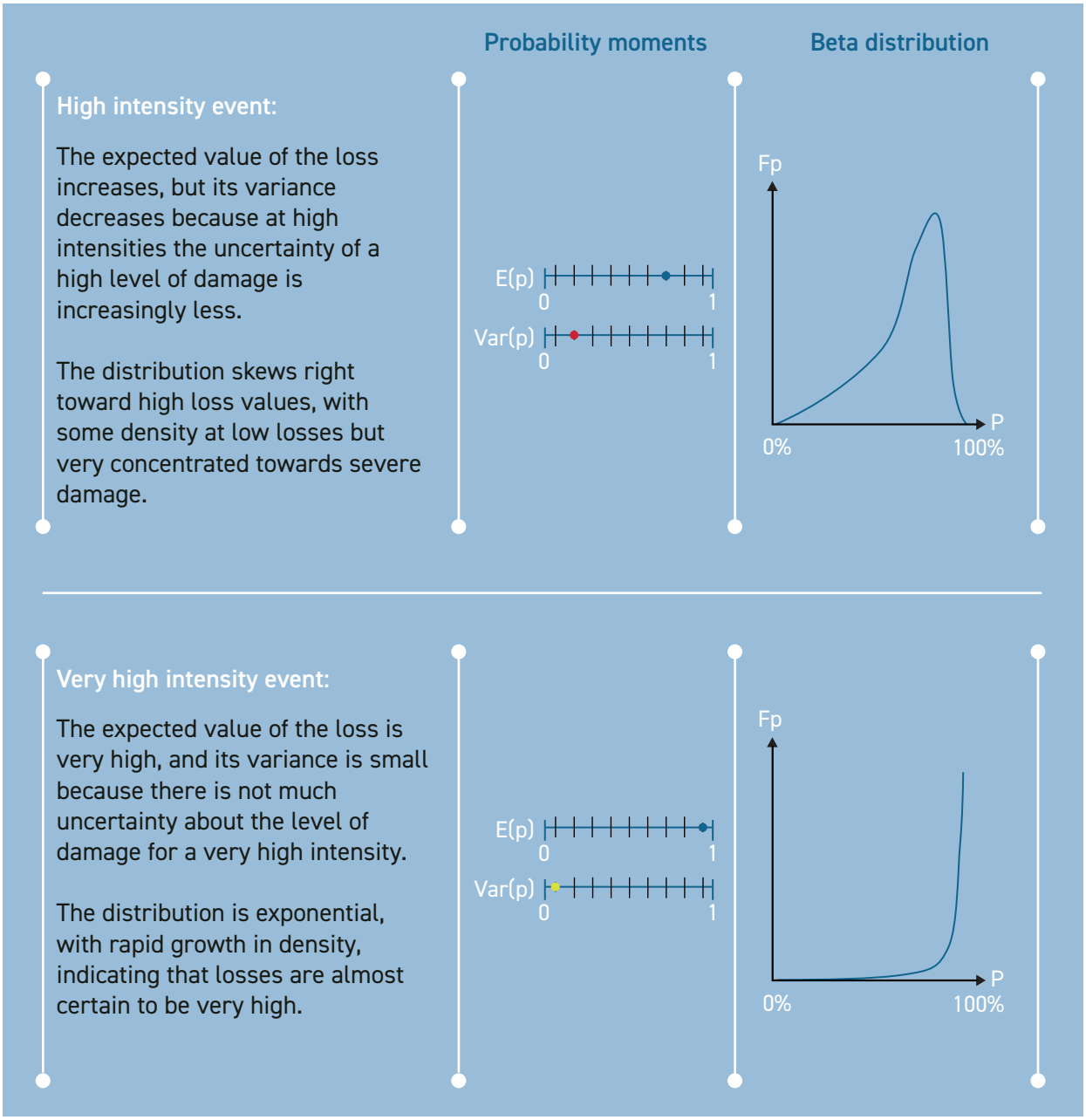
1. It describes a continuous random variable within the real interval [0,1]
2. It is defined using only two parameters. (α and β)
3. It can take multiple shapes depending on the values of these parameters

Since this is a two-parameter distribution, two probability moments are required to characterize it. This implies that vulnerability models must consider at least two moments of the probability distribution. Typically, vulnerability models are defined in terms of the expected value and variance of the loss. The shape of the Beta distribution varies depending on the values of these estimated probability moments. As noted, the Beta distribution's flexibility changes its shape within the defined interval is one of the criteria that makes it widely used in catastrophe risk modelling. Table 5.9 illustrates the expected shapes of the Beta distribution for various combinations of expected value and variance of the loss.

The table includes a general description of what is expected for hazard events at different intensity levels, an illustration of quantities for the expected value and variance within the [0,1] interval, and an illustration of the expected shape of the Beta distribution. From this, it can be concluded that the Beta distribution is a suitable model for the distribution of losses associated with events of different characteristics.

Table 5.9: Beta distribution variation based on event intensity

Description	Probability moments	Beta distribution
Very low intensity event: A low-loss value is expected with low dispersion. That is, if the intensity is very low, the loss will be low and relatively stable. The distribution exhibits negative exponential behaviour, with a rapid decrease. That is, the highest probability density is concentrated near zero loss, as expected for a very low intensity.		
Low intensity event: The expected value of the loss increases, and its variance also increases (i.e., the loss is more uncertain). The distribution is wider, more right-skewed, and still skewed towards low losses.		
Intermediate intensity event: The expected value of the loss is much higher, and the variance is also as high as possible. The distribution is now symmetrical, bell-shaped, and as wide as possible, indicating that this is the point of greatest possible variability for the loss.		

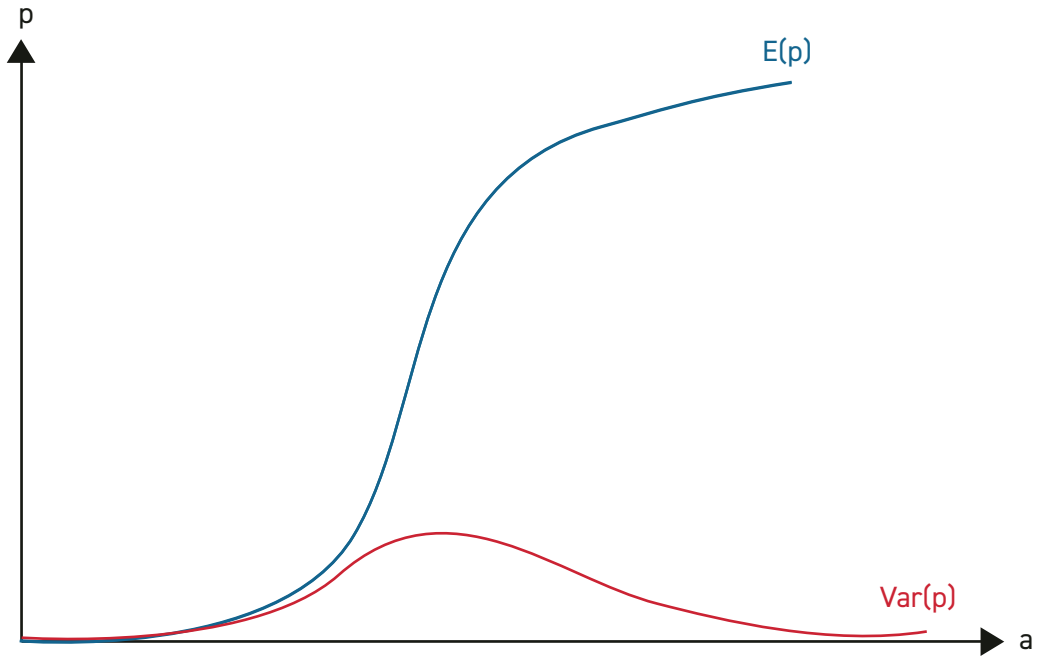


Vulnerability Functions

Vulnerability functions are mathematical representations of physical vulnerability, composed of two functions: one function describes how the expected value of the loss changes with the intensity of the event, while the other describes the variation in the variance. Vulnerability functions are the preferred model for assessing losses to property or infrastructure during catastrophic risk assessments because they effectively describe the loss.

The form of the expected value and variance functions is not entirely free. As illustrated in Table 5.2, the expected value function must always be increasing. In contrast, the variance function typically increases initially and then decreases. This pattern is necessary to accurately reflect the expected variability associated with the intensity of the phenomenon. Figure 5.10 illustrates a typical shape of vulnerability functions.

Figure 5.10: A vulnerability function

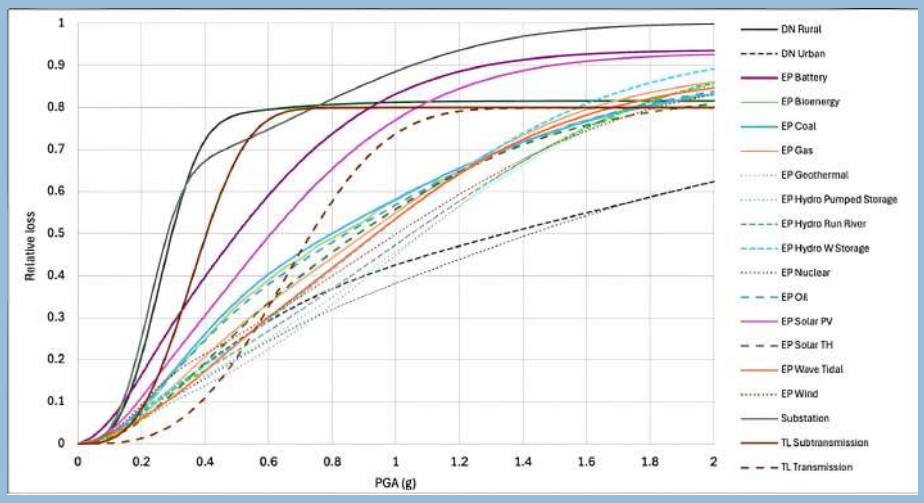


Vulnerability functions are defined for types of exposed elements, based on a defined categorization. This means that a single function can describe the behaviour of multiple exposed elements within the same category. This approach is beneficial because of the probabilistic nature of these functions, which enables the capture of similar behaviours among related exposed elements. The typification or categorization of exposed elements is established in the exposure model based, typically, on the construction or functional characteristics of the elements.

The vulnerability functions developed by Cardona et al. (2023) for various infrastructure archetypes are used in this assignment. These functions are the same as those used in the GIRI model by CDRI. The GIRI library of archetype functions is currently the most comprehensive resource available for infrastructure vulnerability models used in catastrophe risk assessment. The vulnerability functions for the risk assessment of India in this assignment are presented in Figures 5.11 to 5.16. As noted above, no vulnerability functions are used for landslide hazard, as it is assumed that the occurrence of a landslide necessarily implies the destruction of the infrastructure element. This assumption is particularly valid for road infrastructure, which is the only one subject to landslides in this assignment.

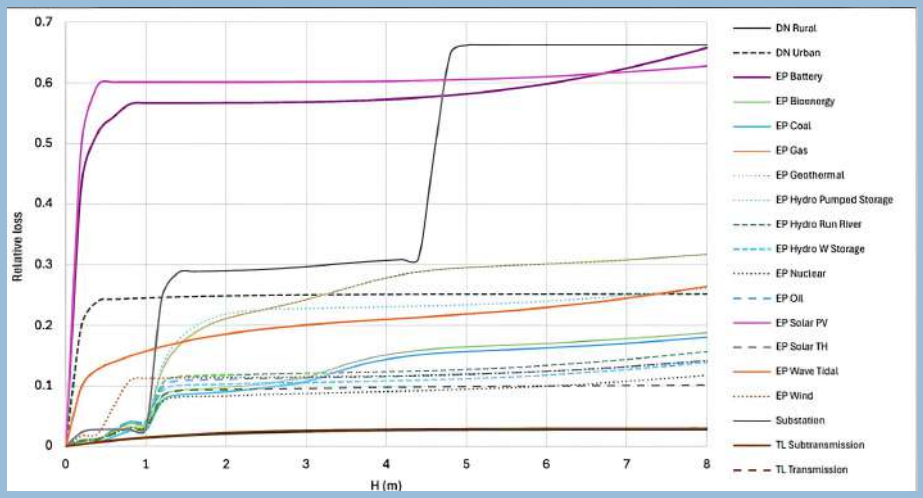
Power Infrastructure

Figure 5.11: Earthquake vulnerability functions for power sector infrastructure



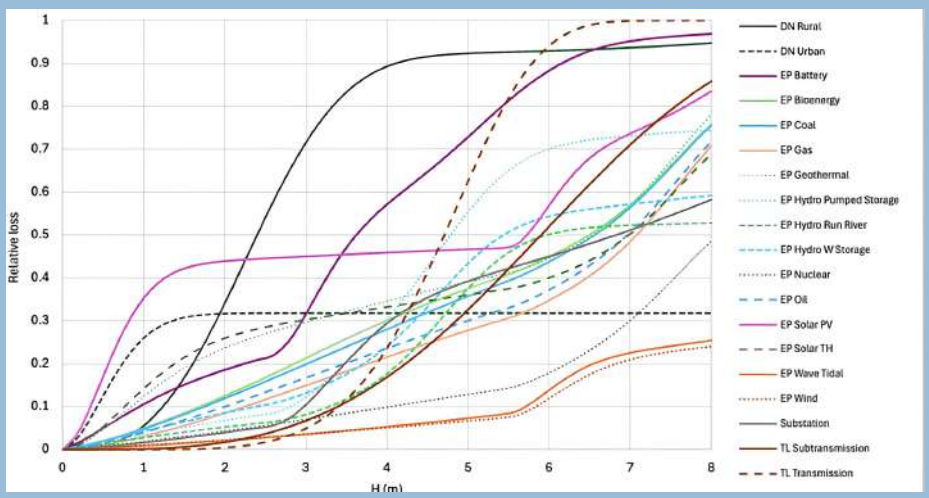
Note: EP = Energy Production, TL = Transmission Line, DN = Distribution Network

Figure 5.12: Flood vulnerability functions for power sector infrastructure



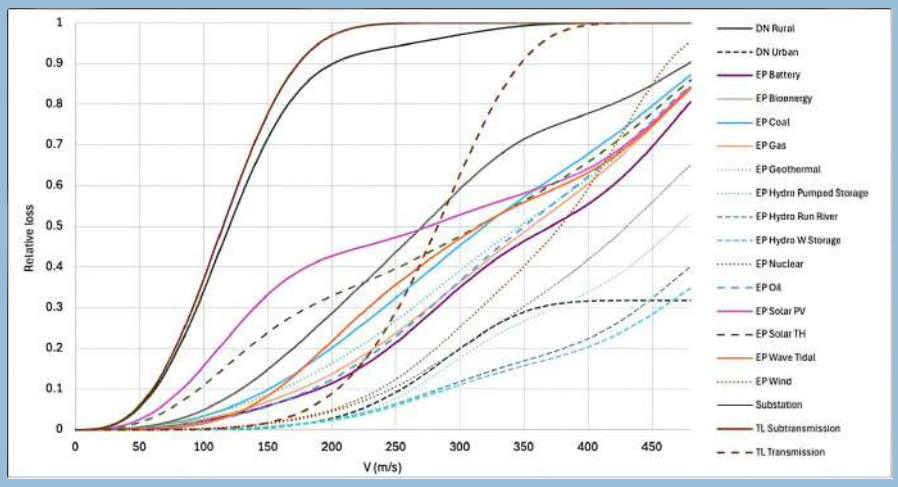
Note: EP = Energy Production, TL = Transmission Line, DN = Distribution Network

Figure 5.13: Storm surge (cyclone) vulnerability functions for power sector infrastructure



EP = Energy Production, TL = Transmission Line, DN = Distribution Network

Figure 5.14: Wind (cyclone) vulnerability functions for power sector infrastructure



Note: EP = Energy Production, TL = Transmission Line, DN = Distribution Network

Road Infrastructure

Figure 5.15: Earthquake vulnerability functions for road sector infrastructure

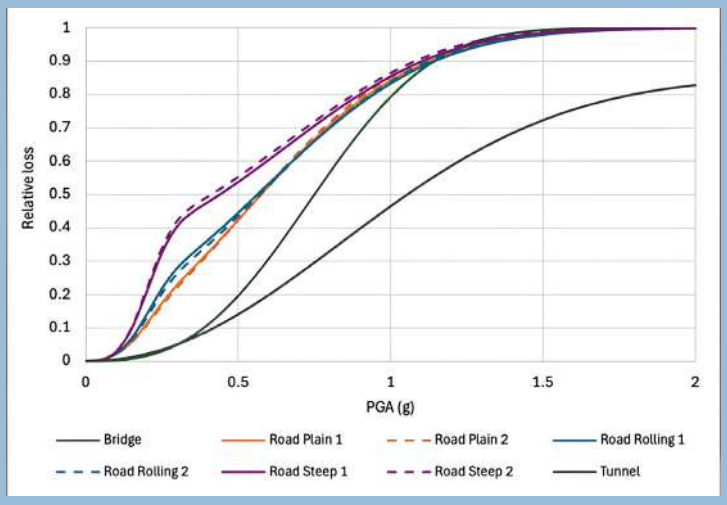
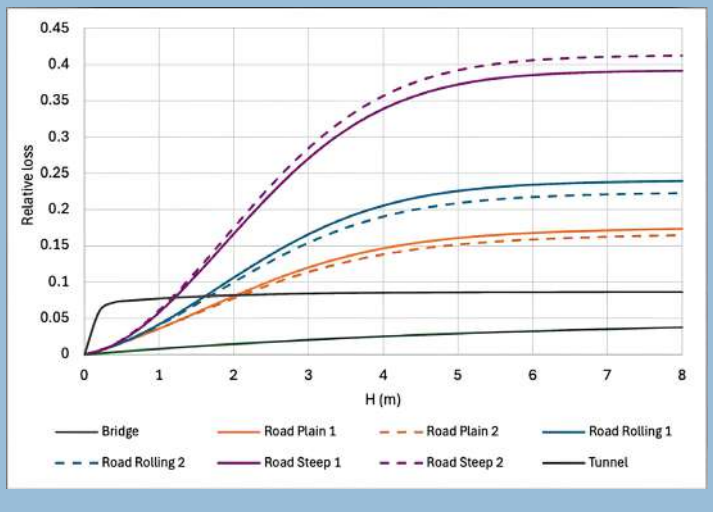


Figure 5.16: Flood vulnerability functions for road sector infrastructure



Risk Assessment Results

Risk results are expressed as the Average Annual Loss (AAL) and the Probable Maximum Loss (PML), standard risk metrics commonly used in catastrophe risk assessments and the insurance industry. While these metrics are formally detailed in Product 1 of this consultancy, we will provide their definitions here for the reader's convenience.



Average Annual Loss:

The AAL is an important indicator as it integrates into a single value the effect, in terms of loss, of the occurrence of hazard scenarios over vulnerable exposed elements. It is considered the most reliable risk indicator due to its ability to summarize the loss-time process and its low sensitivity to uncertainty. The AAL represents the expected value of annual losses and indicates the amount needed to be paid long term to cover all future losses. In a simple insurance scheme, the AAL would correspond to the annual pure premium.



Probable Maximum Loss:

This is a loss that does not occur frequently, that is, a loss usually associated with long return periods. Instead of a single PML value, there exists a complete curve (loss versus return period). However, it is common practice to define a specific PML value by fixing a return period. There are no universally accepted standards for what constitutes 'not very frequently'. In the insurance industry, for example, the return periods used to define the PML can range from 200 to 2,500 years.

The AAL is presented as a total for each hazard-sector combination and disaggregated by subsector and other relevant characteristics. Furthermore, the AAL is disaggregated into risk maps that illustrate the geographical variation in expected losses. In all these types of results, AAL values may be presented as absolute or relative. Absolute AAL refers to the modelled amount expressed in monetary units. In contrast, relative AAL is the same amount but divided or normalized by the exposure value under consideration. For example, if the AAL is provided for an entire sector within a territory, the relative AAL is normalized by the total exposed value of that sector. On the other hand, if the reported AAL pertains to a single exposed element (such as in risk maps), the relative AAL is normalized by the exposure value of that element alone. In this report, relative AALs are always presented as per-thousand fractions with the symbol ‰.

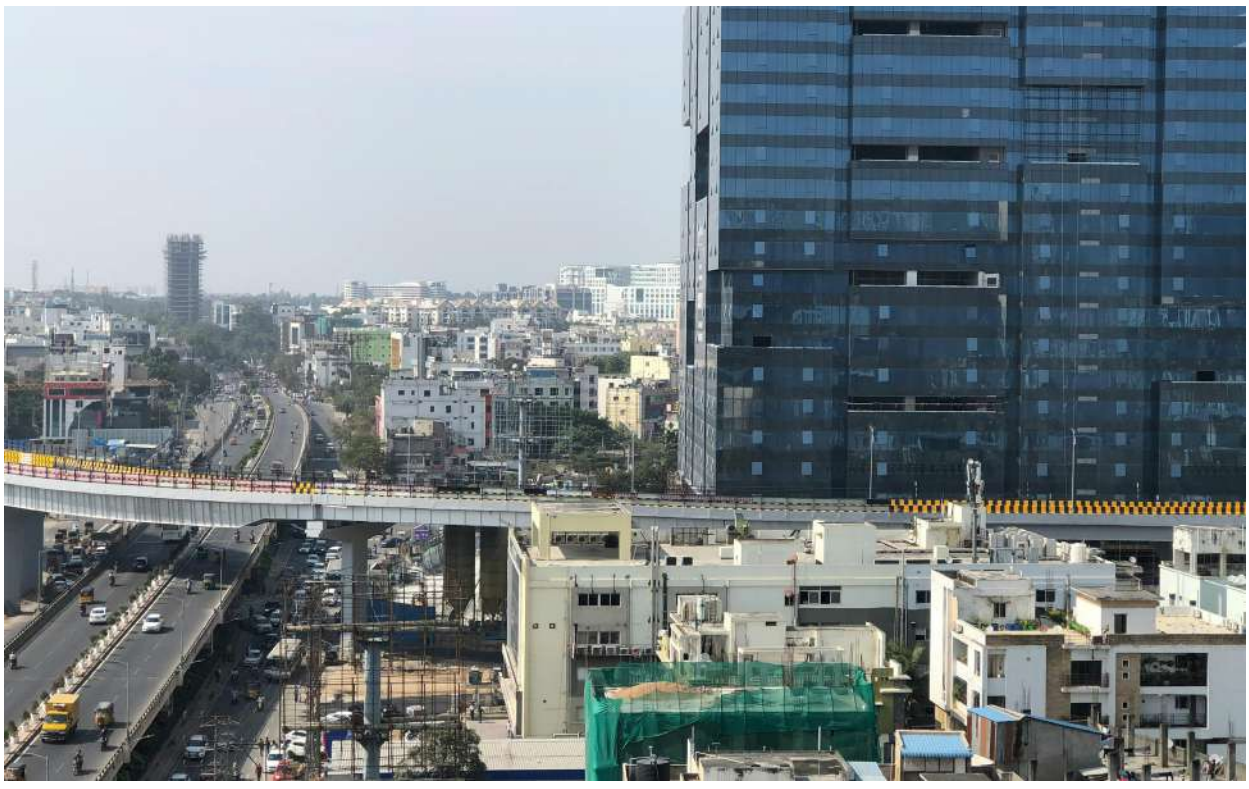
The PML is presented as a function of loss versus return period, for each hazard and sector. Both absolute and relative PML values are included. Relative PML values are presented to facilitate comparison among hazards. For the AALs, absolute PMLs are calculated, whereas relative PMLs are normalized by the sector-exposed value. Given that PMLs are derived from large quantiles in probability distributions, they cannot be disaggregated to produce maps. In this report, relative PMLs are always presented as per-hundred fractions with the symbol %.

Power Infrastructure

Table 5.10 presents the AAL for India's power sector for the hazards considered in this assessment, both in absolute and relative terms. It is noteworthy that the largest losses are due to floods, with the climate scenario SSP5-RCP8.5 yielding the highest losses, followed closely by those in climate SSP1-RCP2.6 and in the current climate. The lower AAL is for earthquakes, primarily because these events occur at low frequencies. AAL is a metric highly dominated by the frequency of the events, which is the reason why floods tend to cause large AAL values while tropical cyclones or earthquakes do not.

Table 5.10: Absolute and relative AAL for power sector infrastructure

Hazard	Average annual Loss	
	$	%
Earthquake	$173,406,000	0.13
Flood	$2,834,687,000	2.15
Flood (RCP2.6)	$3,167,580,000	2.41
Flood (RCP8.5)	$3,917,122,000	2.98
Tropical cyclone	$592,303,000	0.45
Tropical cyclone	$477,318,000	0.36



The relative AAL across subsectors is shown in the figure below. In the case of earthquake hazard (see Figure 5.17), the highest relative AAL is observed for the Generation and Distributions subsectors. This is reasonable, as earthquakes can cause correlated losses across multiple locations for a single event. For floods (see Figure 5.18), the largest AAL is seen in the Distribution subsector, followed by the Generation subsector. For Transmission, the AAL is low, as expected, since most elements of this subsector, particularly transmission lines, are elevated. In addition, there is a noticeable increase in AAL due to climate change, particularly under the SSP5-RCP8.5 scenario, affecting all subsectors. Finally, the AALs for tropical cyclones (see Figure 5.19) show greater participation by the Generation subsector, with lower values for Transmission and Distribution. This difference is attributed to the greater sensitivity of power plants and facilities to wind, compared with the relatively lower wind sensitivity of Transmission or Distribution infrastructure, such as transmission towers or substations.

Figure 5.17: Relative AAL from earthquake for power infrastructure portfolios

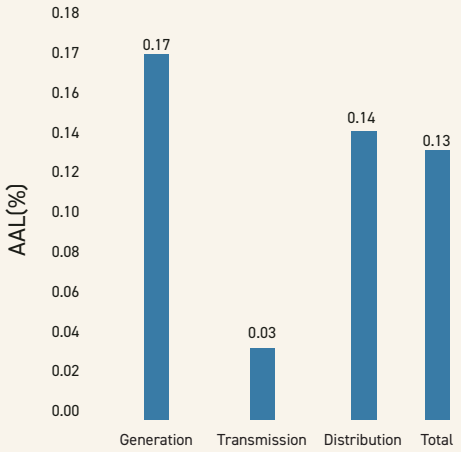


Figure 5.18: Relative AAL from flood for power infrastructure portfolios

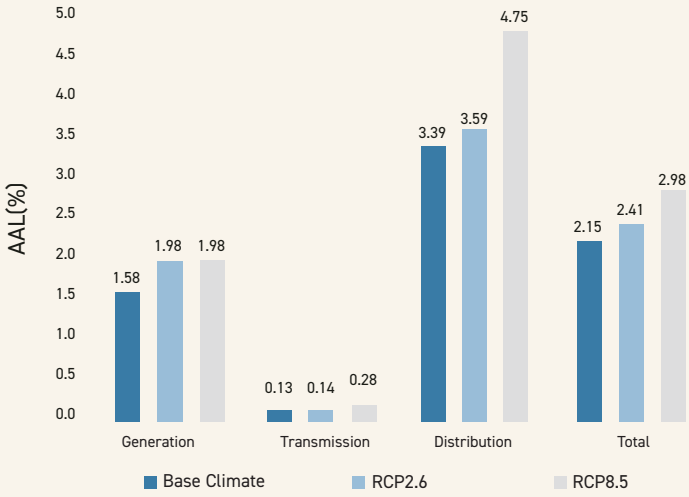
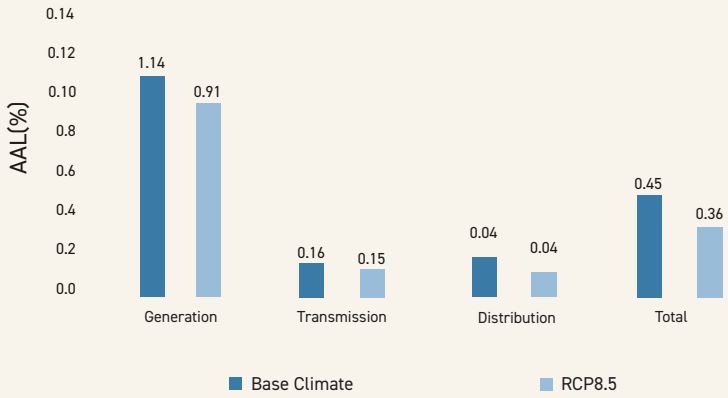


Figure 5.19: Relative AAL from tropical cyclone for power infrastructure portfolios



The AAL of each subsector is determined by aggregating the individual losses calculated for each exposed element. Each element in the exposure portfolio has a unique set of location, price, and vulnerability conditions, resulting in distinct risk evaluations. The AAL is further broken down by element to illustrate these differences and the individual characteristics of each element within the risk landscape. Despite India's large size, the maps presented below clearly illustrate the variation in the relative AAL among the exposed elements. Figures 5.20 to 5.25 display the relative AALs for elements in the power sector across all hazards and climate scenarios considered.

It is noteworthy that a complete dataset with geolocated vector information of exposed elements will be provided to ADPC, enabling further consultation of the extensive results generated.

Figure 5.20: Relative AAL from earthquakes for power portfolios

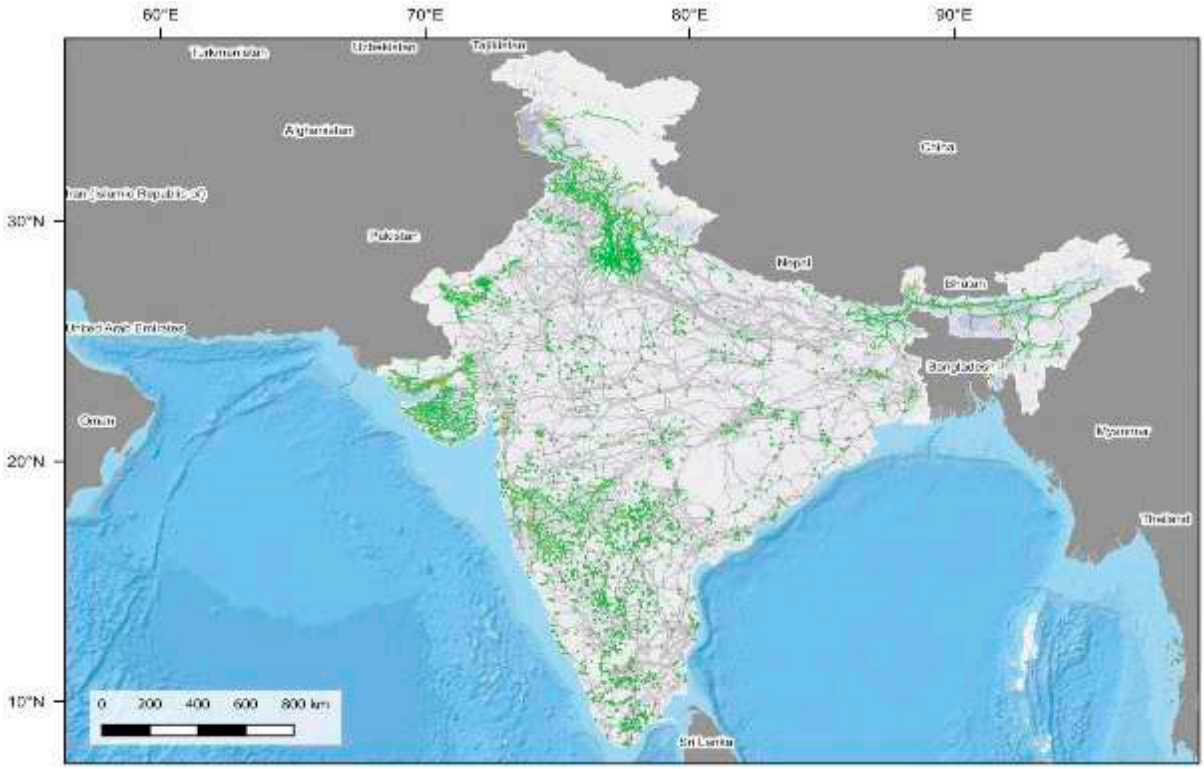




Figure 5.21: Relative AAL from floods for power portfolios

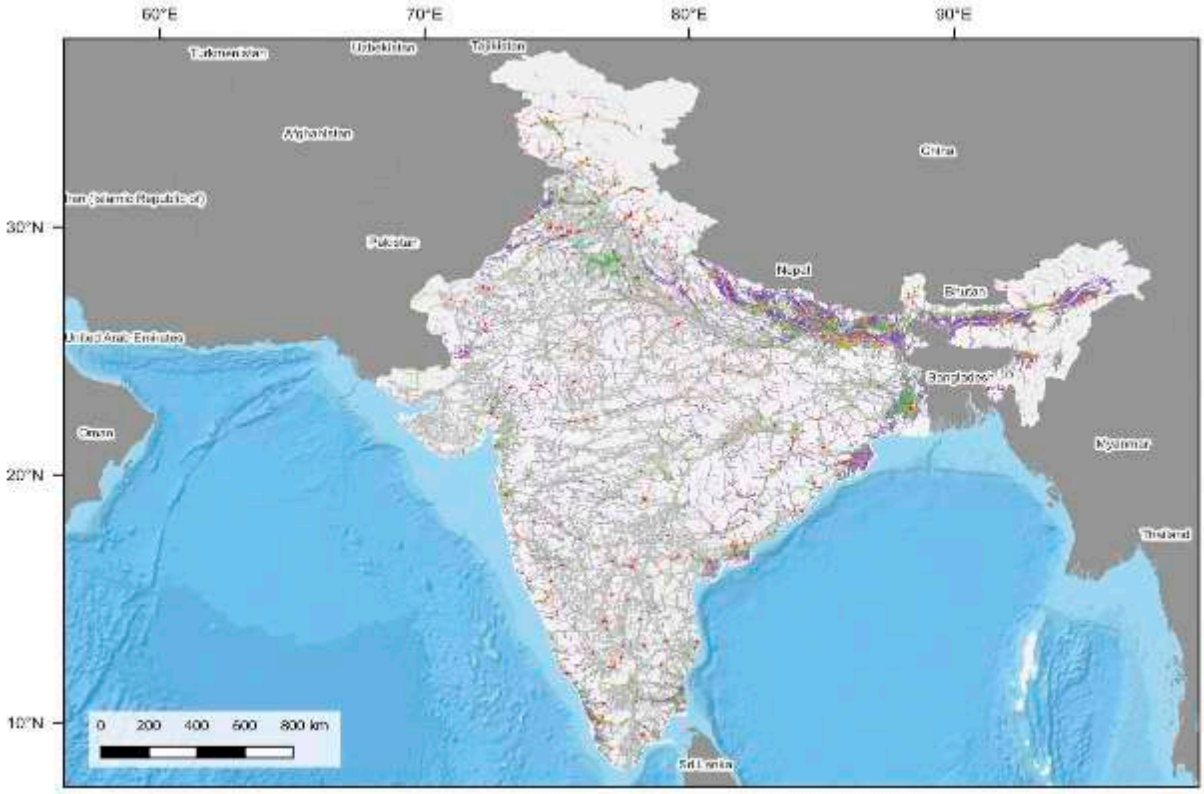


Figure 5.22: Relative AAL from floods (SSP1-RCP2.6) for power portfolios

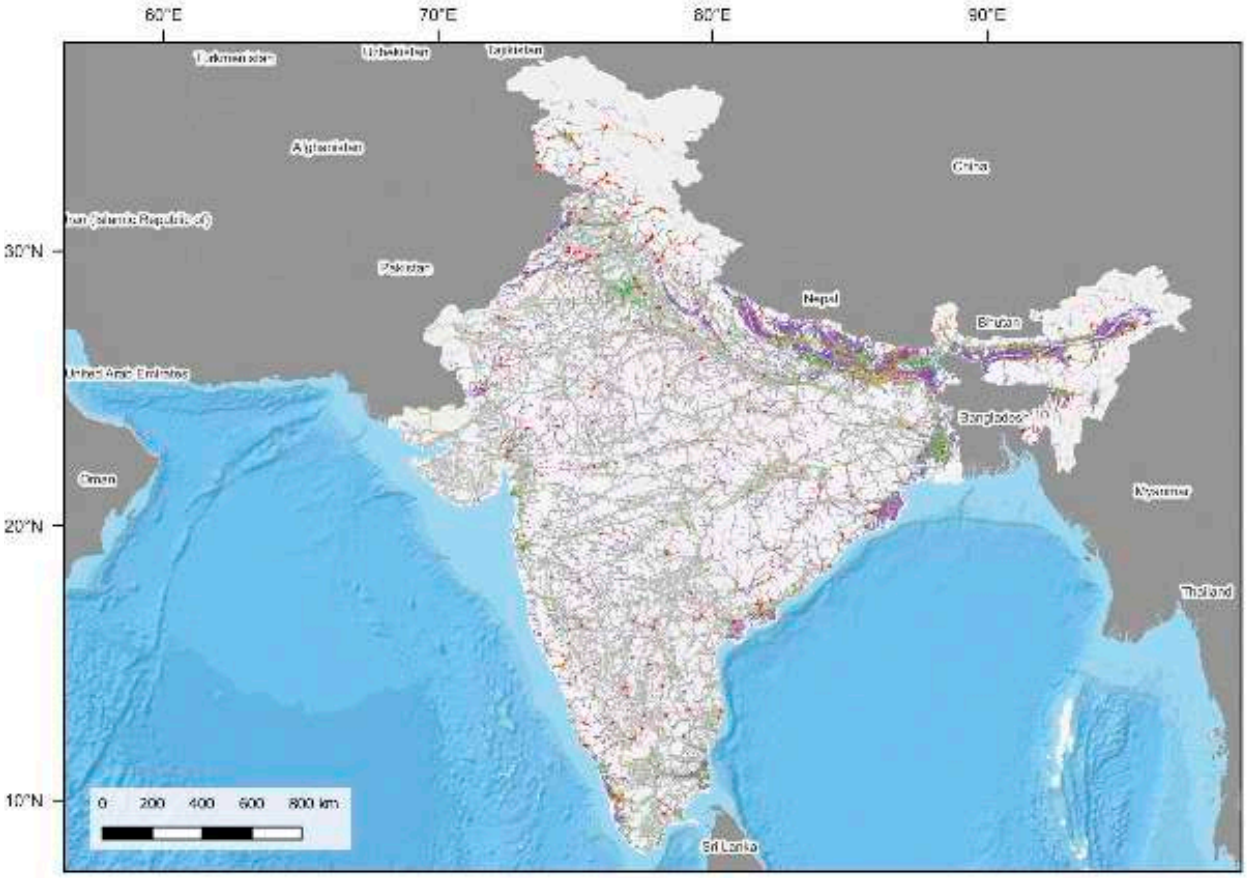


Figure 5.23: Relative AAL from floods (SSP5-RCP8.5) for power portfolios

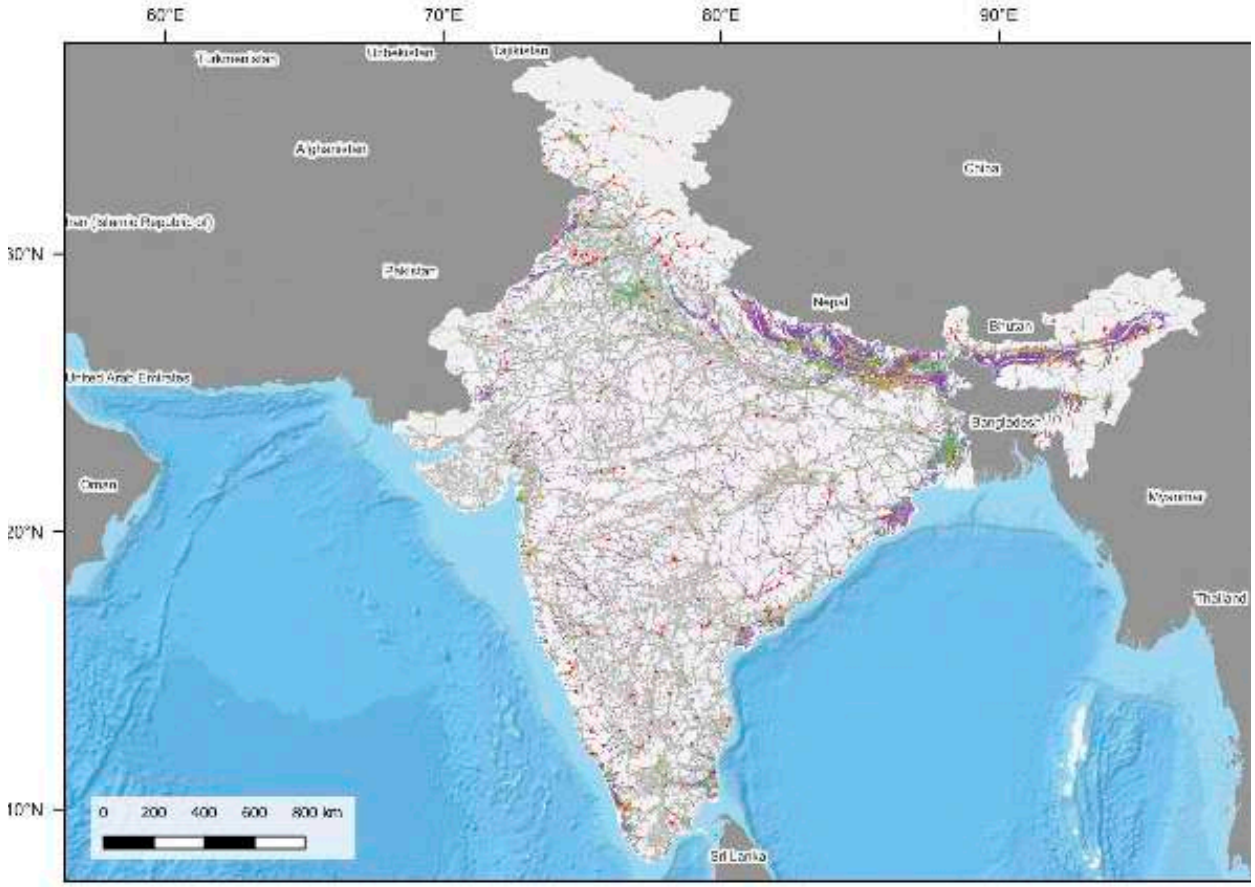


Figure 5.24: Relative AAL from tropical cyclones for power portfolios

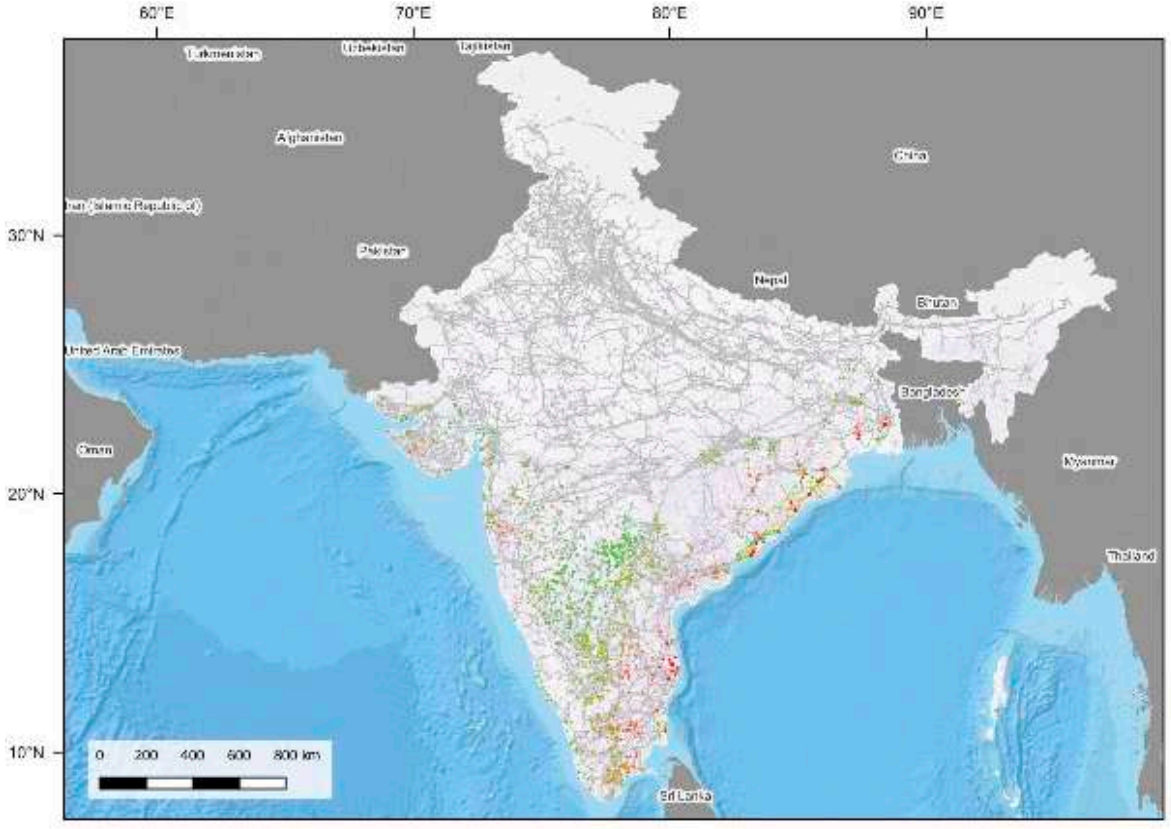


Figure 5.25: Relative AAL from tropical cyclones (SSP5-RCP8.5) for power portfolios

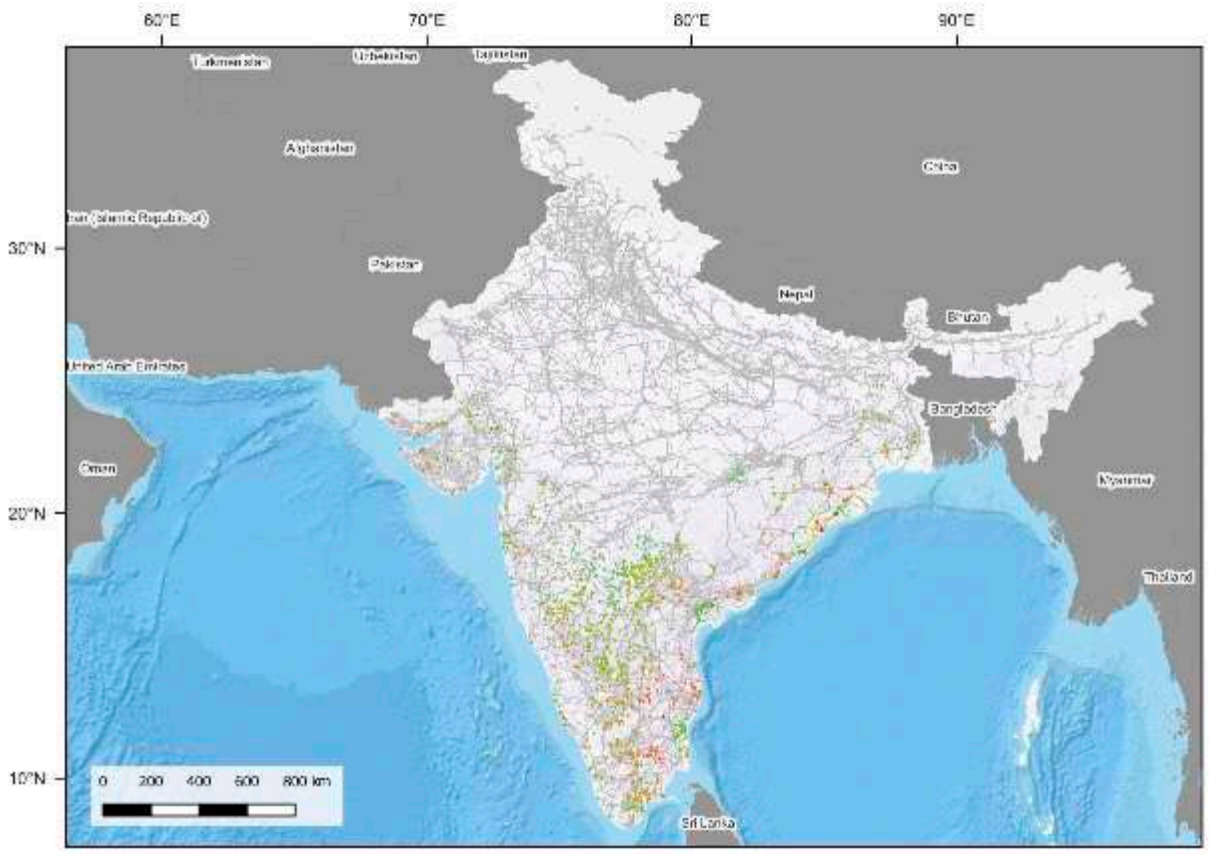


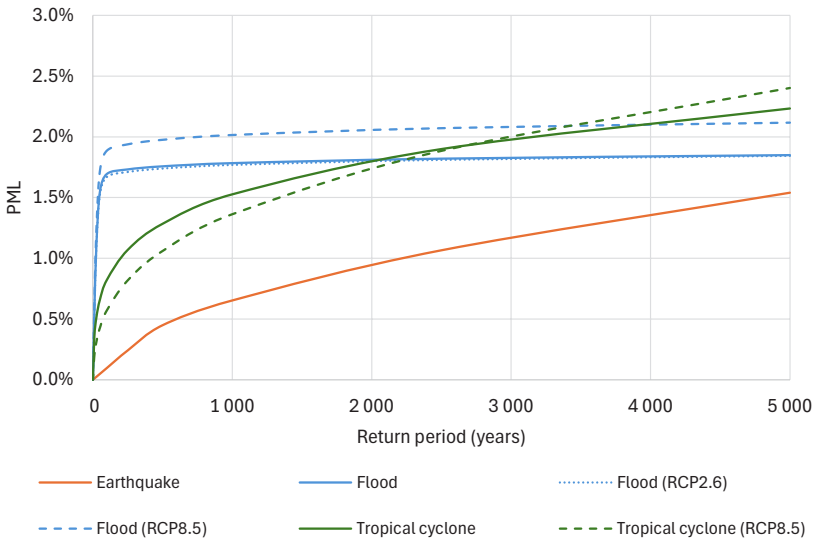
Table 5.11 presents the PML values for the Indian power sector, categorized by hazard type and selected return periods. PMLs are generally higher in magnitude than AALs due to their definition and the nature of their calculation. Figure 5.26 illustrates these PMLs in relative terms, showing the variation of this metric across different return periods. For longer return periods, the risks associated with earthquakes and floods dominate this sector, with flood risk surpassing earthquake risk specifically under the climate SSP5-RCP8.5. Additionally, it is noteworthy that the PML function for earthquakes and tropical cyclones increases more rapidly compared to the relatively stable PML curve for floods. This difference is primarily attributable to the frequency of hazard events.



Table 5.11: PML for the Energy Sector Infrastructure (Values In $)

Return period (years)	Eartquake	Flood	Flood (RCP 2.6)	Flood (RCP 8.5)	Tropical cyclone	Tropical cyclone (RCP 8.5)
10	$233,668,000	$6,083,433,000	$6,789,836,000	$8,426,768,000	$7,023,504,000	$14,510,201,000
25	$584,170,000	$12,408,310,000	$13,826,873,000	$17,245,636,000	$14,411,043,000	$29,653,946,000
50	$1,168,339,000	$17,156,884,000	$19,120,255,000	$23,851,525,000	$20,288,594,000	$41,008,409,000
100	$2,336,679,000	$18,878,889,000	$21,075,140,000	$26,188,640,000	$23,411,819,000	$45,067,529,000
250	$5,841,697,000	$19,515,185,000	$21,862,124,000	$26,948,741,000	$27,703,821,000	$46,463,927,000
500	$10,339,885,000	$19,992,380,000	$22,467,773,000	$27,497,841,000	$32,807,658,000	$47,490,221,000
1,000	$14,032,231,000	$20,509,547,000	$23,132,396,000	$28,083,747,000	$37,164,627,000	$48,593,294,000
2,500	$20,849,071,000	$21,259,699,000	$24,110,582,000	$28,918,318,000	$44,959,653,000	$50,178,016,000
5,000	$28,012,859,000	$21,881,883,000	$24,933,704,000	$29,598,157,000	$52,946,562,000	$51,480,040,000

Figure 5.22: PML Curve for the Energy Sector Infrastructure



Road Infrastructure

Table 5.12 presents the AAL for India's road sector based on the hazards considered in this assessment, presented in both absolute and relative terms. The data reveal that the highest losses are attributable to rain-triggered landslides, particularly in the SSP5-RCP8.5 scenario, followed closely by the SSP1-RCP2.6 scenario and the current climate conditions. Additionally, floods contribute to the overall AAL in a manner consistent with the respective climate scenarios. Finally, earthquakes and earthquake-triggered landslides contribute the least to the AAL. As mentioned, this pattern is influenced by the frequency of events: hydrometeorological hazards such as floods and rain-triggered landslides occur relatively frequently, whereas earthquakes and the landslides they trigger are less common.

Table 5.12: Absolute and Relative AAL for the Roads and Bridges Infrastructure

Hazard	Average annual Loss	
	$	%
Earthquake	$71,302,000	0.15
Landslide - Earthquake	$28,310,000	0.06
Flood	$177,852,000	0.36
Flood (RCP2.6)	$194,293,000	0.40
Flood (RCP8.5)	$271,450,000	0.55
Landslide - Rain	$323,849,000	0.66
Landslide - Rain (RCP2.6)	$410,352,000	0.83
Landslide - Rain (RCP8.5)	$442,896,000	0.90

The relative AAL across subsectors is shown in the figure below. In the case of earthquake hazard (see Figure 5.27), the highest AAL is seen in the expressways and national highways subsectors. This seems logical, given the extensive exposure of this subsector across the country, which allows an earthquake to impact multiple roads in various locations. However, it is worth noting that the AALs for earthquakes, as well as for earthquake-triggered landslides (see Figure 5.28), are relatively low. Furthermore, the distribution patterns of these two hazards are similar across sectors, which is expected given their causal relationship.

In the case of floods (see Figure 5.29), the largest AAL occurs on expressways and national highways, followed by major district roads and state highways, with consistent results across all subsectors. This is in contrast to the AALs for rain-triggered landslides (see Figure 5.30), where, again, the higher values are for expressways and national highways, followed by state highways and major district roads, but in smaller proportions. The difference is largely due to population density being higher in valleys and near rivers than in mountainous regions. A similar trend is observed for bridges: AALs for floods are higher than for landslides. This is primarily because rivers are the main obstacle that bridges must overcome, making them more vulnerable to floods than to landslides.

Figure 5.27: Relative AAL from earthquake for road and bridges infrastructure portfolios

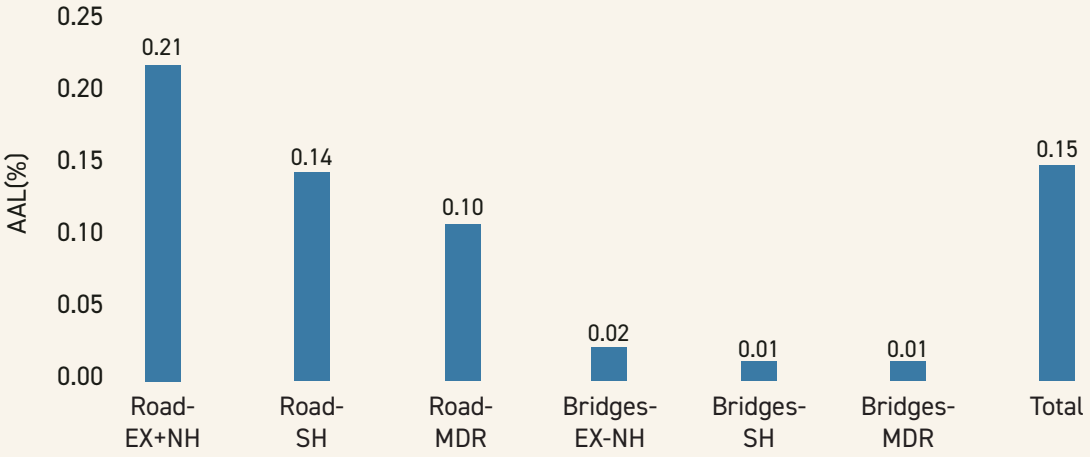


Figure 5.28: Relative AAL from earthquake-triggered landslides for road and bridges infrastructure portfolios

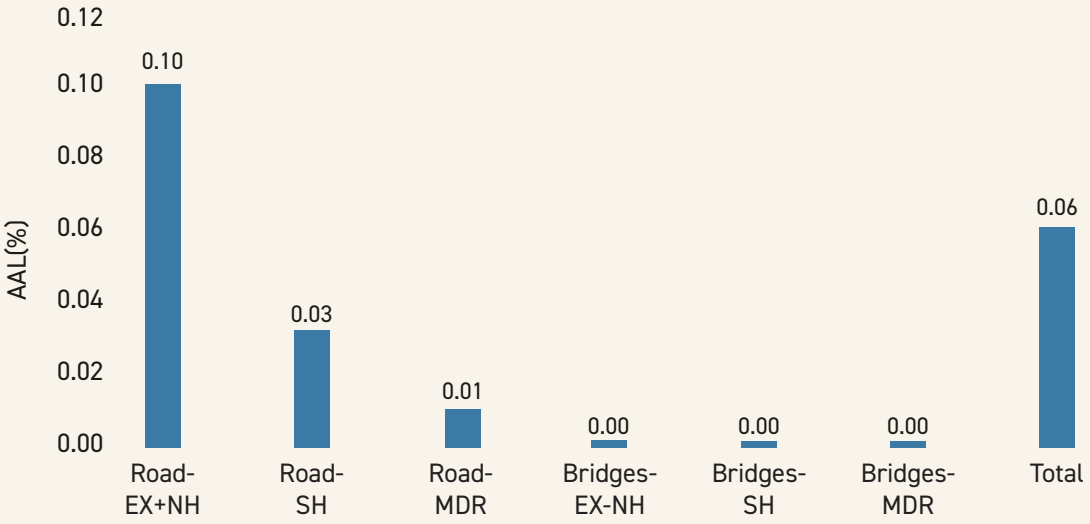


Figure 5.29: Relative AAL from flood for road and bridges infrastructure portfolios

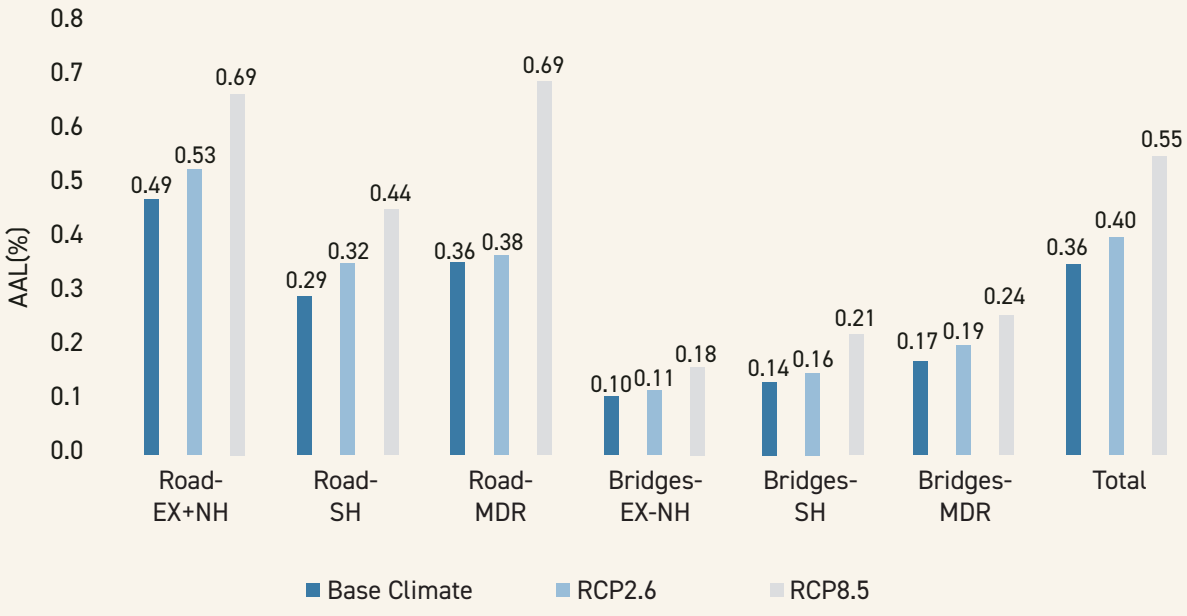
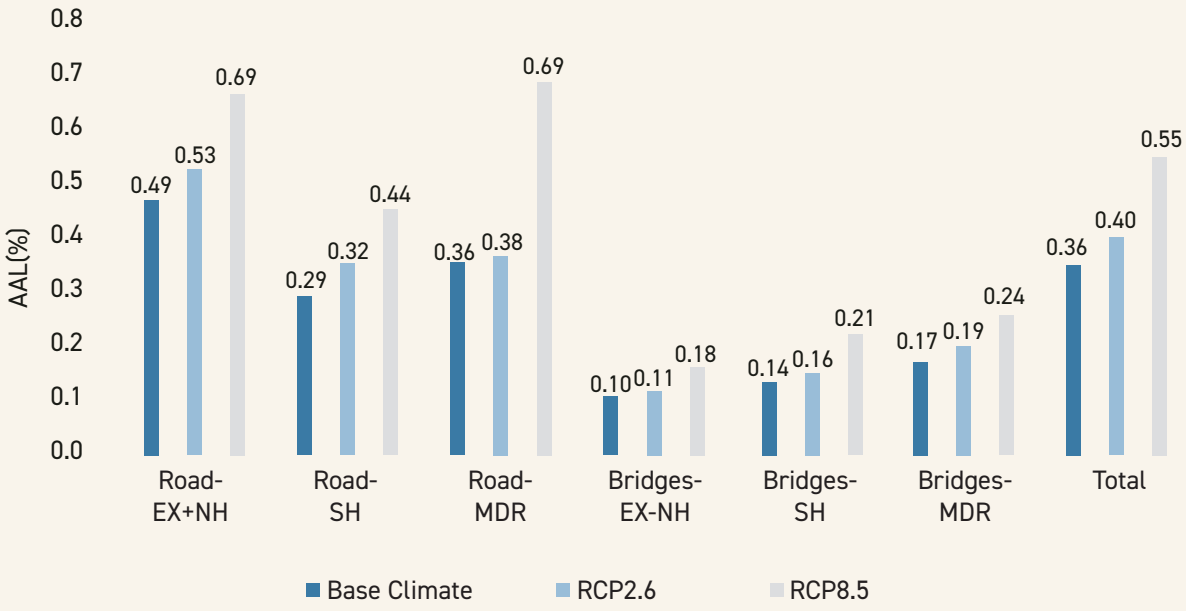


Figure 5.30: Relative AAL from rain-triggered landslides for road and bridges infrastructure portfolios



The AAL of each road segment in the model is presented in Figures 5.31 to 5.38, for each hazard. The maps clearly illustrate variation in the relative AAL across the exposed elements of the road network, despite the country's large size. As noted above, a complete geolocated dataset will be delivered to ADPC, enabling a more detailed consultation.

Figure 5.31: Relative AAL from earthquakes for road portfolios

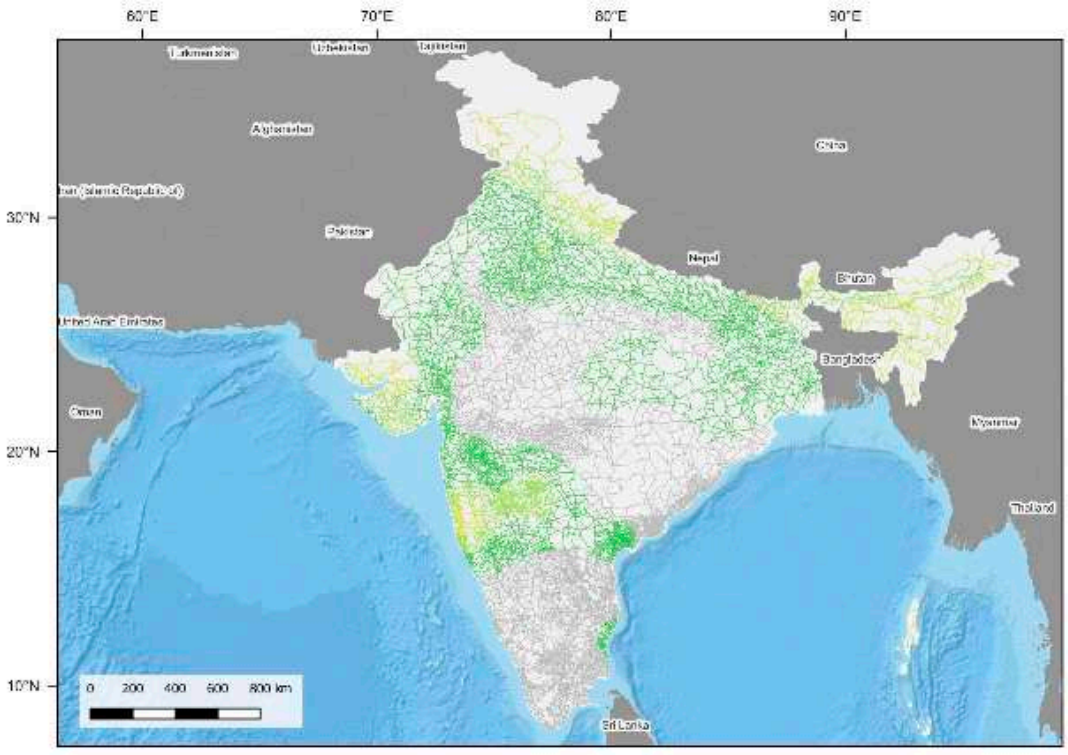


Figure 5.32: Relative AAL from earthquake-triggered landslides for road portfolios

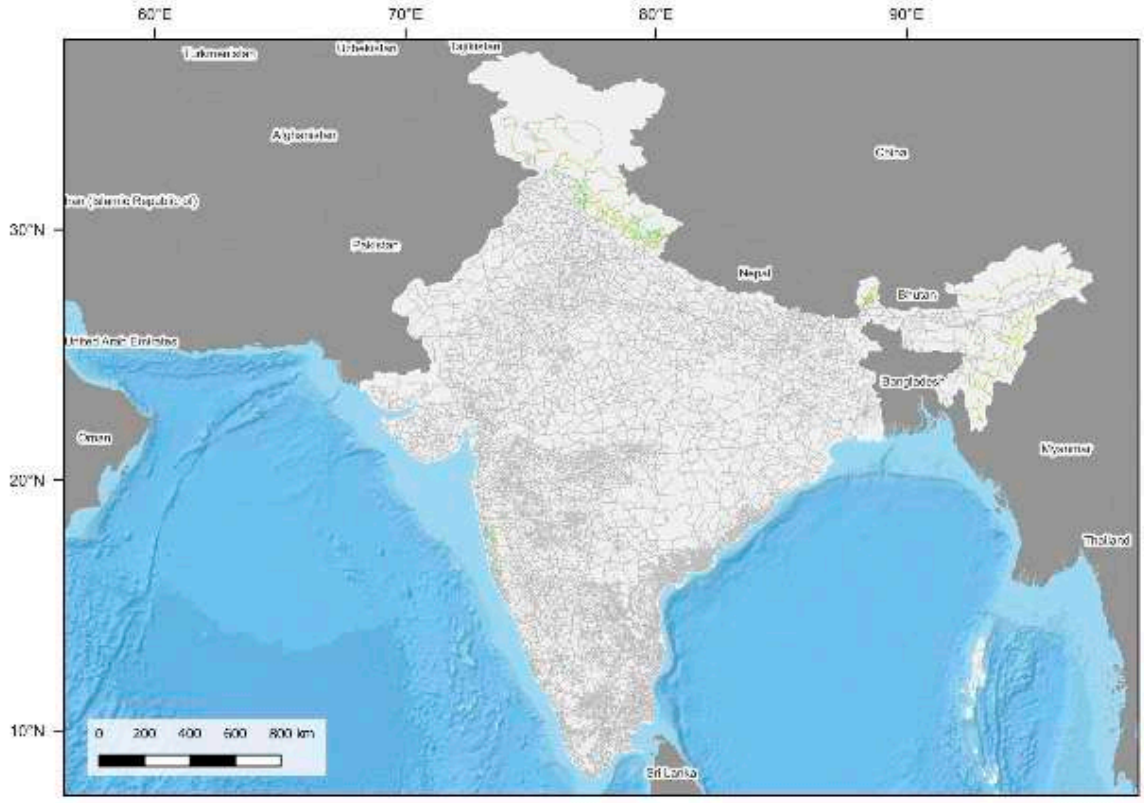


Figure 5.33: Relative AAL from floods for road portfolios

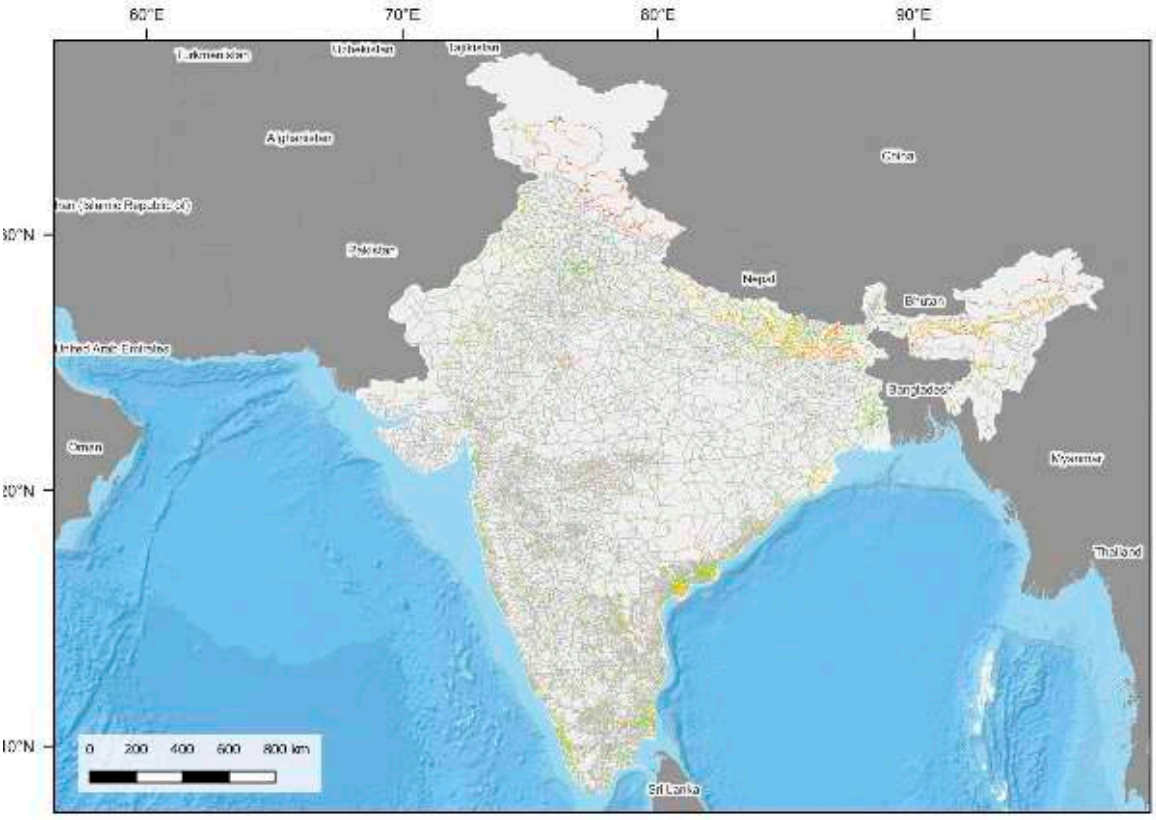


Figure 5.34: Relative AAL from floods (SSP1-RCP2.6) for road portfolios

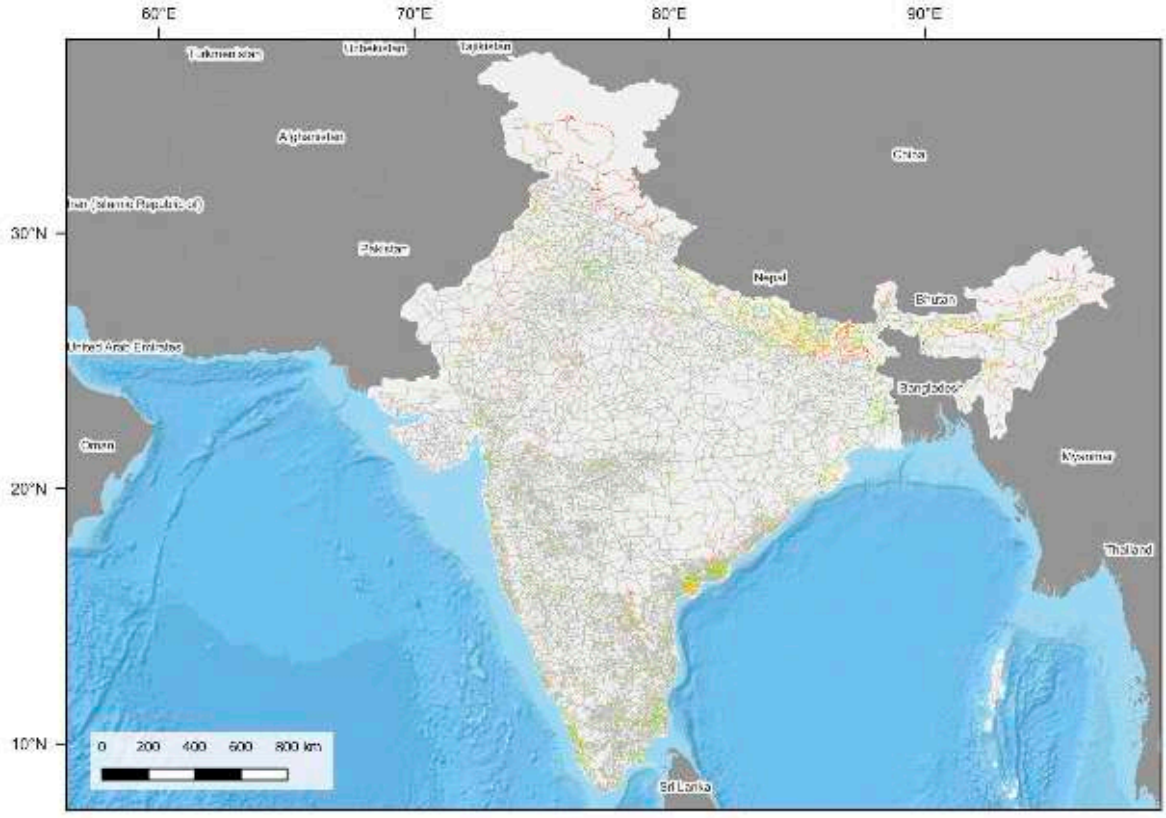


Figure 5.35: Relative AAL from floods (SSP5-RCP8.5) for road portfolios

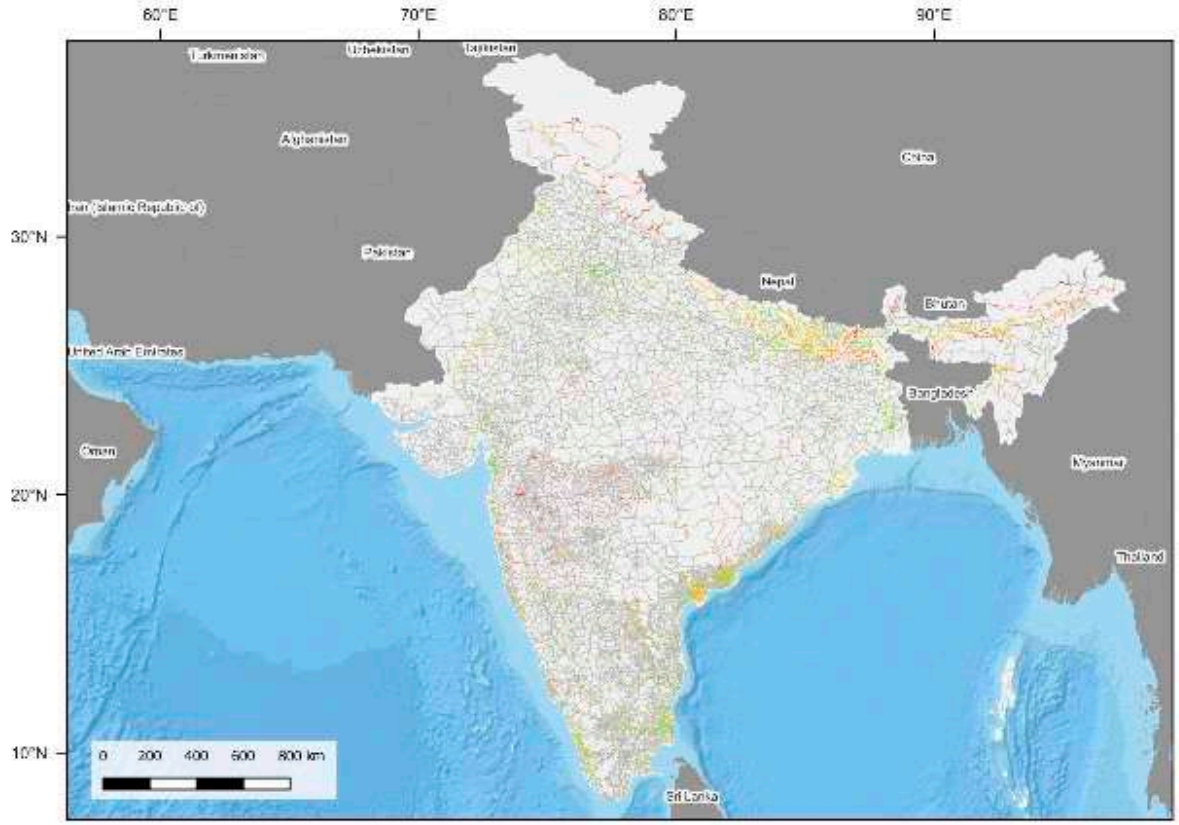


Figure 5.36: Relative AAL from rain-triggered landslides for road portfolios

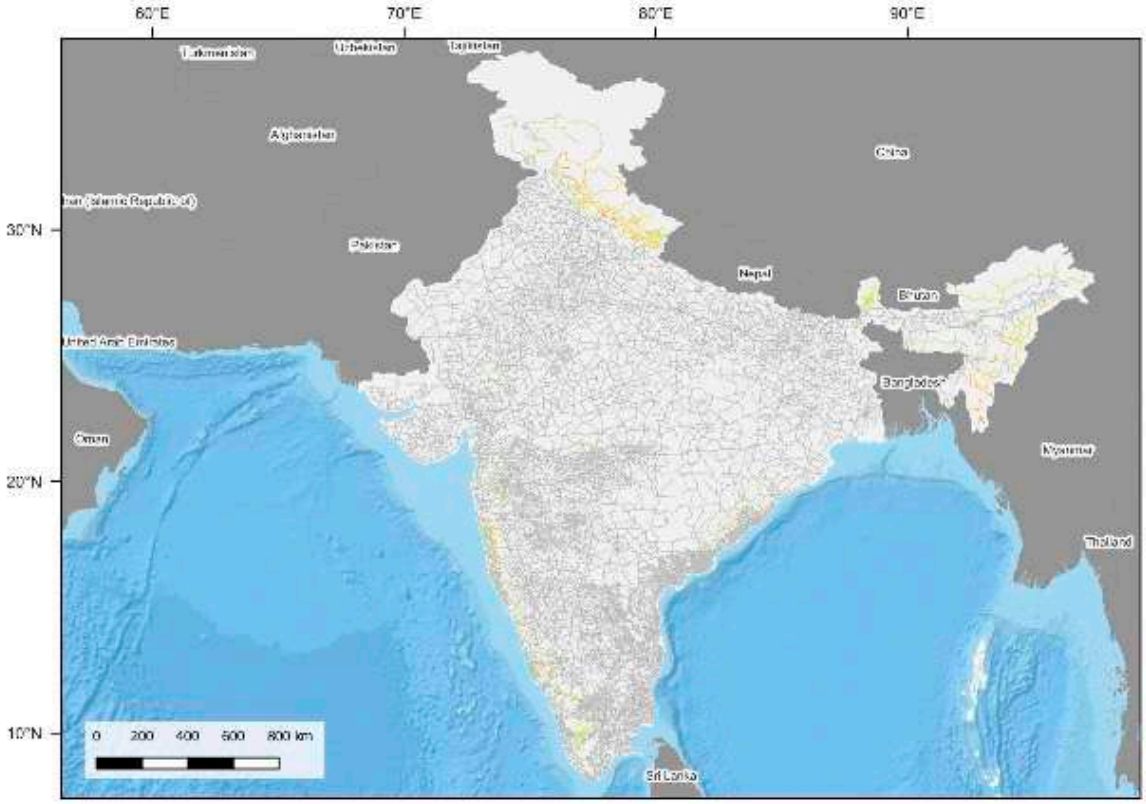


Figure 5.37: Relative AAL from rain-triggered landslides (SSP1-RCP2.6) for road portfolios

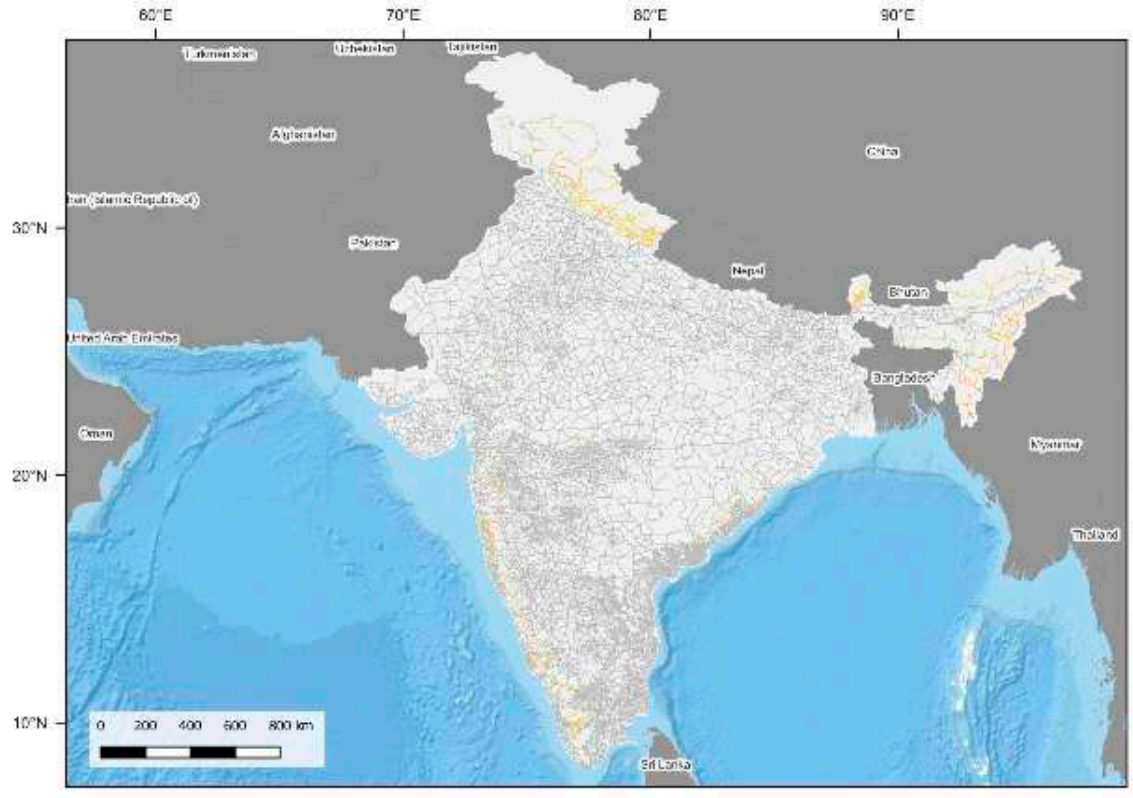


Figure 5.38: Relative AAL from rain-triggered landslides (SSP5-RCP8.5) for road portfolios

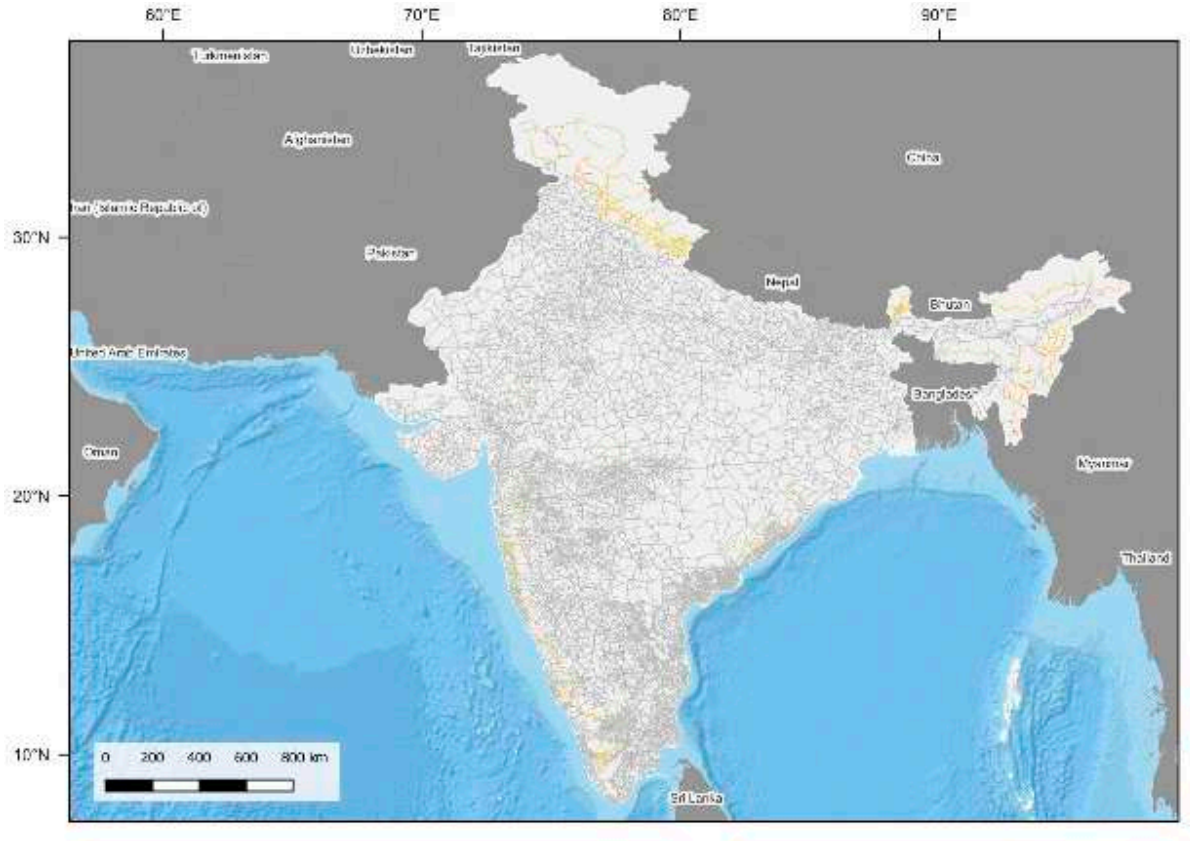




Table 5.13 presents the PML values for India's road sector, categorized by hazard and various selected return periods. As mentioned, PMLs are always greater in magnitude than AALs across all calculated return periods.

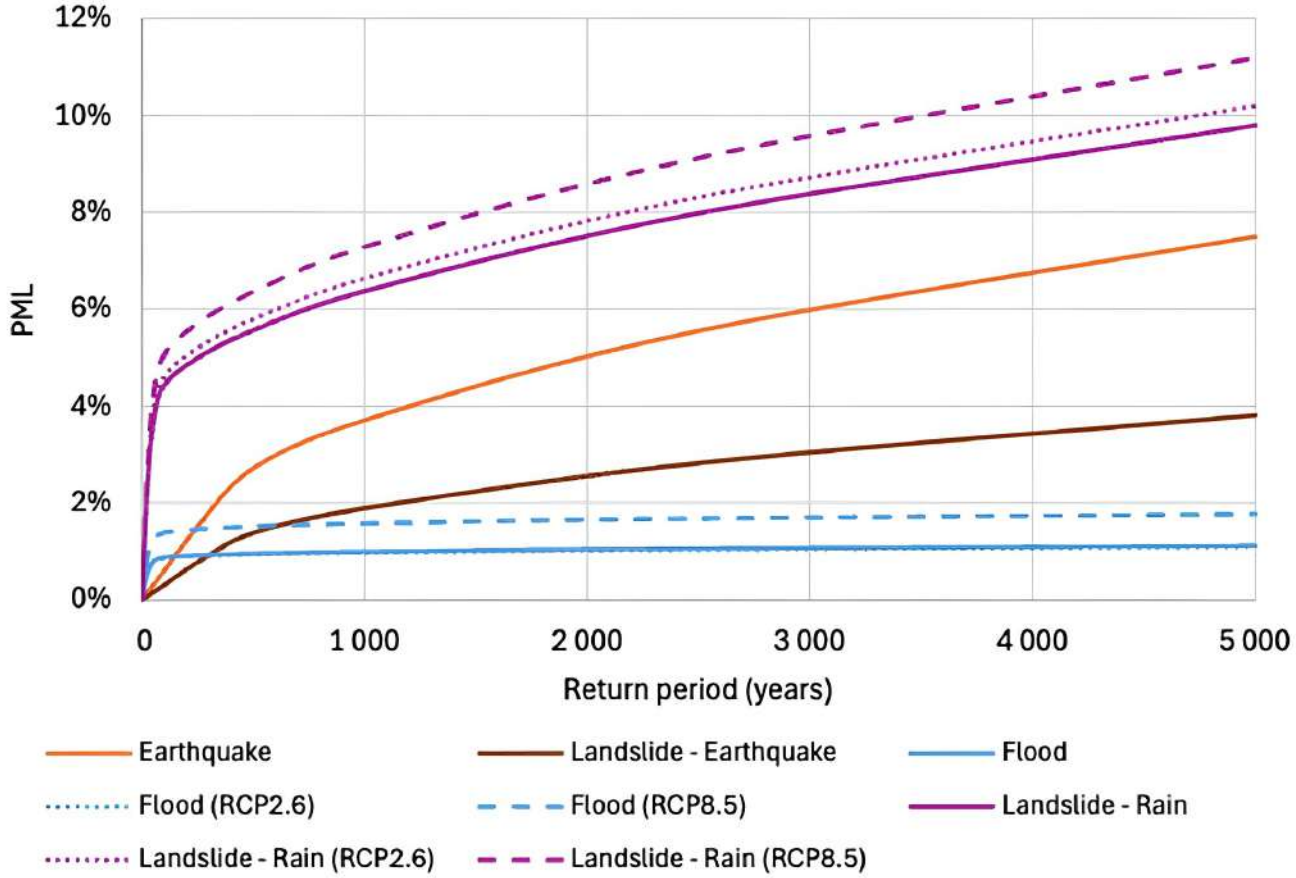
Table 5.13: PML for roads and bridges infrastructure (values in thousand $)

Return period (years)	Earthquake	Lanslide - Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
10	$95,976	$38,539	$381,301	$416,551	$581,785	$673,405	$853,277	$920,948
25	$239,939	$96,348	$777,612	$849,455	$1,185,848	$1,463,962	$1,854,998	$2,002,112
50	$479,878	$192,697	$1,078,910	$1,178,474	$1,644,911	$2,232,382	$2,828,670	$3,053,003
100	$959,757	$385,393	$1,199,246	$1,309,605	$1,827,889	$2,697,708	$3,418,289	$3,689,382
250	$2,399,391	$963,483	$1,265,610	$1,381,398	$1,927,984	$3,035,473	$3,846,273	$4,151,308
500	$4,257,123	$1,653,674	$1,322,519	$1,442,814	$2,013,473	$3,382,866	$4,286,458	$4,626,402
1000	$5,796,348	$2,190,438	$1,389,205	$1,514,669	$2,113,352	$3,874,477	$4,909,382	$5,298,729
2500	$8,650,843	$3,148,718	$1,495,185	$1,628,653	$2,271,533	$4,850,279	$6,145,829	$6,633,234
5000	$11,663,691	$4,123,460	$1,591,386	$1,731,935	$2,414,631	$5,950,176	$7,539,518	$8,137,452

Figure 5.39 presents the relative PML curves for all the hazards considered. Although rain-triggered landslides and floods dominate the risk landscape for very short return periods, the earthquake PML rapidly surpasses those for return periods beyond 500 years, indicating the stronger influence of this hazard on the risk for large or catastrophic events. For very long return periods, even the earthquake-triggered PML exceeds the PML for floods, again due to the lower frequency but higher consequences of earthquake-induced landslides, relative to floods. As mentioned above, the rate of increase of the earthquake and earthquake-triggered PML functions is far higher than the PML curve for rain-triggered landslides and the rather flat curve for floods.



Figure 5.39: PML curve for roads and bridges infrastructure





Chapter 6

Post-Disaster Funding Gap Assessment



Post-Disaster Funding Gap Assessment

Conducting a timely funding-gap assessment is critical to ensuring that affected sectors receive the resources necessary to rebuild and recover effectively and efficiently. Because it is a multi-faceted process, it requires multiple perspectives to ensure fiscal resilience. There are advantages in undertaking a funding gap assessment. Funding gap assessments can do the following:

1. Provide decision-makers with crucial data for informed resource allocation during different recovery stages. By identifying funding gaps and understanding the financial requirements of various recovery initiatives, stakeholders can systematically prioritize projects and reallocate funds to address new or escalating needs related to efficiency and impact.

2. Provide a structured and data-driven approach to understanding the specific financial needs for recovery. The information enables decision-makers, governments, and organizations to mobilize resources by advocating for additional funding from sources such as government budgets, international donors, private-sector partnerships, grants, and loans.

3. Can be used to advocate for additional funding from governments, international organizations, donors, and the private sector. Resource mobilization is a pivotal component of ensuring effective disaster recovery. Funding gap assessments play a crucial role in this process, guiding stakeholders in identifying the most critical resources and determining how to leverage them strategically to support recovery initiatives.

4. Enhance transparency and accountability in the recovery process, allowing stakeholders to monitor the allocation and utilization of funds, which helps reduce the risk of corruption and mismanagement.

5. Help ensure that there are no unnecessary bottlenecks in funding availability, allowing for a quicker and more efficient response to recovery needs without delays.

6. Enable international donors and humanitarian organizations to target their aid and donations effectively, allowing them to direct resources to areas with the greatest need and maximizing the impact of their assistance.

Disasters pose serious fiscal risks to India. Unexpected shocks can create significant challenges that disrupt the government's finances, severely impairing the economy's smooth functioning.

Fiscal Risks from Disasters in India

India faces significant fiscal risks due to frequent and high-impact disasters, including floods, cyclones, and droughts. Between 2000 and 2019, the EM-DAT database recorded more than 300 major disasters in India, affecting over 1.2 billion people and resulting in nearly 80,000 fatalities. During this period, the average annual LYL was approximately 4.8 million. Severe events, such as the 2007 Bihar floods and the 2004 Indian Ocean tsunami, accounted for the largest losses.

Economic modelling indicates that government expenditure increases by about 0.17 percent of GDP (which is equivalent to roughly INR 94–97 billion) following an average disaster year. This increase reflects the immediate fiscal pressure associated with disaster response and recovery. Although central government debt also rises slightly, this increase is not statistically significant.

These findings highlight the significant fiscal risks linked to recurring disasters in India. As climate variability and urbanization continue to heighten disaster risks, it is crucial to strengthen financial preparedness and ensure timely access to post-disaster funds to maintain fiscal stability.

Estimating Future Funding Gaps for Power and Roads and Bridges

In estimating future post-disaster funding gaps, the hazard with the maximum effect in a short return period will be used. The data are based on the table of findings in the catastrophe model. The discussion is limited to the government allocation and the projected losses to the power and roads and bridges sectors.

Power

In the absence of climate change effects, floods were identified as the hazard with the greatest adverse impact on the power sector in terms of average annual loss (AAL). According to the results from the catastrophe model, the AAL for the energy/power sector due to floods is approximately $2,835 million, which can be aggravated by climate change (RCP8.5) up to $3,917 million.

Without climate change effects, the highest probable maximum loss (PML) for the power sector from hazards with a 10-year return period is attributable to tropical cyclones, at about $7,024 million, which can reach up to $ 14,510,201,000 under the RCP8.5 scenario.

Roads and Bridges

Based on the results of the catastrophe model, without climate change effects, rainfall-induced landslides have the highest estimated AAL for roads and bridges, ranging from $324 million to $443 million under the RCP8.5 scenario.

Among the identified hazards, rainfall-induced landslides have the highest PML for roads and bridges with a return period of 10 years, ranging from $673 million to $921 million under the RCP8.5 scenario. However, for hazards with longer return periods (500–5,000 years), earthquakes pose a greater risk. Earthquakes with a return period of 500 years have PMLs of approximately $4,257 million, whereas

landslides at around $3,383 million. For hazards with a return period of 5,000 years, earthquakes are estimated to cause PMLs of $11,664 million, compared with landslides at $8,137 million under the RCP8.5 scenario.

Funding Gaps based on Estimated AAL Without Climate Change Effects

Based on the 16th Finance Commission, the allocations for the period 2026–27 to 2030–31 are the following (Government of India, Ministry of Home Affairs, Disaster Management Division n.d.):

The **State Disaster Response Fund** has a total allocation of INR 1,63,521crore, comprising INR 1,24,732.65 crore as the central share and the state share of INR 38,788.35 crore. This is part of the broader SDRMF, which totals INR 2,04,401crore. Out of this total, INR 40,880 crore is allocated to the SDMF.

The **National Disaster Response Fund** has an allocation of INR 63,524.8 crore over the designated period. This is part of the total NDRMF, which amounts to INR 79,406 crore, including the mitigation component of INR 15,881.2 crore.

Table 6.1 shows the annual allocation from the central and state governments. The total SDRF and NDRF allocations, respectively, are divided by 5 years.

Table 6.1: Annual Allocation of Funds for Disaster Response in India ($ = INR 87)

SDRF						
Year	Central share		State share		Total SDRF	
	INR crore	$ Mill	INR crore	$ Mill	INR crore	$ Mill
From 2026-27 to 2030-31	1,24,732.65	14,337.09	38,788.35	4,458.43	1,63,521	18,795.52
Annual allocation	24,946.53	2,867.42	7757.67	891.69	32,704.20	3,759.10
NDRF						
Allocation for 2026-27 to 2030-31					63,524.8	7,301.70
Annual allocation					12,704.96	1,460.34

Based on the figures above, if floods and landslides caused by rain occur between 2025 and 2026, Table 6.2 shows the gap between the disaster response funds (NDRF and SDRF) and the AALs for the energy and roads and bridges sectors.

Table 6.2: Annual NDRF and SDRF and the AALs for power/energy and roads and bridges

NDRF		Central share		State share		AAL ($ Million)		Gap/surplus	
INR crore	$ million	INR crore	$ million	INR crore	$ million	Power	Roads and Bridges	$ million	INR crore
12,704.96	1,460.34	24,946.53	2,867.42	7757.67	891.69	2,835	324	2060.41	1,792.56

Table 6.2 indicates that India's total disaster response fund can cover the AALs of power and roads and bridges. It should be noted that the country's total disaster fund is intended to cover the post-disaster needs of all sectors. For instance, if the Kerala floods and Cyclone Fani, with estimated damages of INR 10,557 crore and INR 16,465 crore, respectively, occur in the same fiscal year, the allocated SDRF and NDRF will be insufficient even for the power/energy and roads and bridges sectors.

Extreme Cases

In analysing the potential post-disaster funding gap due to PML, the following scenarios are considered.

Scenario 1.

Hazards with a return period of 10 years, without climate change effects occurring in 2026–27. This scenario represents the least-cost option as hazards with longer return periods typically yield higher PMLs.

1. The highest PML for the power sector is projected to result from tropical cyclones, estimated at approximately $7,024 million. This amount could increase to $14,510 million under the RCP8.5 scenario, assuming a 10-year return period.
2. For roads and bridges, landslides caused by rainfall pose the highest PML with a return period of 10 years, which is about $673 million up to $921 million under the RCP8.5 scenario.
3. The total disaster response fund available for the year is approximately $5,219.44 million (which includes both the central and state shares of the NDRF and SDRF).

Using the figures for tropical cyclones (for the power sector) and landslides due to rain (for roads and bridges), Table 6.3 shows that the NDRF and SDRF cannot accommodate the PMLs for the power and roads and bridges sectors if such hazards occur together in a year.

Table 6.3: Annual NDRF and SDRF, plus the highest PMLs for power and roads and bridges with a 10-year return period

NDRF		Central share		State share		AAL ($ Million)		Gap/surplus	
INR crore	$ million	INR crore	$ million	INR crore	$ million	Power	Roads and Bridges	$ million	INR crore
12,704.96	1,460.34	24,946.53	2,867.42	7757.67	891.69	7,024	673	2,478.59	21,563.73

Scenario 2.

Hazards with various return periods without climate change projected impacts, and with the highest PMLs occurring in 2026–27. If hazards with the highest PMLs by various return periods occur within the 2026–27 fiscal year, there will be a huge funding gap, as shown in Table 6.4. The total disaster response fund for the year is approximately $ 4,205 million (which includes both the central and state shares of the NDRF and SDRF).

Table 6.4: Funding gap based on highest PMLs by various return periods

Return period (Years)	PML ($ Million) by Hazard				Gap/Surplus	
	Power		Roads and bridges			
	$ million	Hazard	$ million	Hazard	$ million	INR crore
10	7,024	Tropical cyclone	673	Landslide-rain	-3,492	-30380
25	14,411	Tropical cyclone	1,464	Landslide-rain	-11,670	-101529
50	20,289	Tropical cyclone	2,232	Landslide-rain	-18,316	-159349
100	23,412	Tropical cyclone	2,698	Landslide-rain	-21,905	-190574
250	27,704	Tropical cyclone	3,035	Landslide-rain	-26,534	-230846
500	32,808	Tropical cyclone	4,257	Earthquake	-32,860	-285882
1,000	37,165	Tropical cyclone	5,796	Earthquake	-38,756	-337177
2,500	44,960	Tropical cyclone	8,651	Earthquake	-49,406	-429832
5,000	52,947	Tropical cyclone	11,664	Earthquake	-60,406	-525532

Table 6.4 indicates that the country's total disaster response fund is insufficient to cover the PMLs of the two sectors under natural hazards with various return periods.

Chapter 7

Recommendations



Recommendations

Based on the analysis presented in this report, the following recommendations are proposed to mitigate fiscal risks associated with disasters affecting critical infrastructure sectors, specifically power, roads and bridges in India. These recommendations are interconnected and are directly informed by the financial data and sectoral findings detailed throughout the report.

1 Make critical infrastructure resilient

To mitigate adverse impacts across sectors, hazards-related risks must be identified and appropriate risk-reduction investments implemented to make critical infrastructure resilient to the severity of future hazards.

a Identify and assess specific critical infrastructure assets and estimate potential damage from disasters and their subsequent impacts on other sectors.

Both the central and state governments should identify their respective critical assets, the potential damage from frequent and extreme disasters, and the impacts on other important sectors of the economy, to enable them to determine the appropriate risk management mechanisms. Aided by updated hazard maps, the assessment of critical infrastructure should lead to further analysis and the identification of appropriate financial risk management mechanisms to adopt, such as which risk can be retained and which can be transferred.

b Assess and improve the structural integrity of infrastructure, especially the power grid and roads and bridges.

Building more robust infrastructure with higher design standards would enable power grids and road networks to withstand more intense hazards. This may be costly, but it will, in the long run, reduce repair costs, service interruptions, and frequent maintenance costs. For instance, Tonga, which is highly vulnerable to cyclones, has begun upgrading its power grid by replacing its low-voltage overhead network with aerial-bundled conductors (ABCs), deploying underground service cables to customer premises, and installing new smart meters (Nicolas et al. 2019). Additionally, structural designs for roads and bridges may be reviewed to ensure they can accommodate the projected effects of climate change, including increased intensities and frequencies of natural hazards. Inspections and maintenance of infrastructure in the power grid and roads and bridges should likewise be conducted regularly to ensure that their vulnerabilities have not increased.

c Update and upgrade hazard maps.

Upgraded hazard maps will improve the accuracy of estimating potential damage to identified critical infrastructure, as noted above. Such estimates will also inform the government's budgeting for emergency response. Moreover, hazard maps are necessary to encourage insurance companies to expand their disaster-related insurance coverage, as they are crucial for risk assessment, pricing, and underwriting, among other applications. The identification of high-risk areas prone to floods, earthquakes, cyclones, and other disasters enables insurers to determine risk levels, coverage eligibility based on the risk exposure of a property, design customized policies for different risk zones, estimate potential losses and maintain adequate financial reserves or reinsurance, and set appropriate premiums for policyholders (Faster Capital 2025).

d Update building codes and regulations and mainstream disaster and climate risks in development planning and investment decisions to minimize adverse disaster effects and impacts.

To institutionalize social and economic resilience, it is essential to update and enforce building codes, land-use plans, and zoning regulations. These standards should be integrated into the planning and design of both public and private investments. Additionally, disaster risk management and the projected impacts of climate change should be systematically incorporated into national and local development strategies, as well as in investment decisions across sectors. This approach ensures that all new public infrastructure is designed to withstand extreme weather events by incorporating disaster-resilient features. For example, the construction of elevated roads, climate-resilient bridges, and enhanced drainage systems should be thoroughly evaluated for their effectiveness in reducing flood risks and transport disruptions. Such forward-looking investments are critical not only for ensuring public safety and service continuity but also for reducing the long-term fiscal burden associated with recurring infrastructure damage. Furthermore, existing assets and older structures may require retrofitting to improve their structural integrity and resilience. Strengthening critical infrastructure in this way reduces vulnerability to future hazards and supports a more sustainable recovery process. In addition, climate-resilient infrastructure can lead to better insurance terms—such as higher coverage limits, lower deductibles, or more comprehensive policies—thereby improving financial protection while reducing long-term costs. Moreover, because insurers often rely on reinsurance to manage their risks, efforts to reduce infrastructure vulnerability can lead to better terms from reinsurers, which in turn can lower overall insurance costs (Swiss Re Institute 2024).



2 Build a nationwide disaster risk database

a To enhance the financial planning process for disaster management and recovery, the central government should require states to establish a comprehensive digital disaster database. This database would compile historical critical information on the impacts of disasters, including comprehensive assessments of fiscal expenditures related to past disasters and detailed reports on infrastructure damages. By establishing such a robust digital risk database, both the central and state governments will be in a better position to conduct thorough risk assessments, enabling more informed budgeting decisions for future contingencies and improving overall disaster preparedness. A comprehensive historical database will also provide vital inputs for macroeconomic analysis of disaster impacts across sectors, as well as for developing more accurate catastrophe models for the states and the country.

3 Facilitate States in developing up a robust DRF framework

a The states through strong climate-responsive institutions and policies can enable not only public investment but also facilitate private investments in both adaption and mitigation.

- Facilitate states to set up financial frameworks/funds that blend both public finance and mobilise resources from local capital markets.
- Facilitate technical knowledge support from multilateral institutions and national think-tanks on creation of market-based risk transfer instruments to alleviate fiscal burden.
- Prioritize capacity building at the state, district and local levels. Provide incentives to technical staff to be housed on a long-term basis in DRM institutions.
- Explore strategies to increase allocations to SDRF & modify SOPs to ensure faster disbursal of NDRF funds. This will enhance speed and flexibility in disaster response, resilience of infrastructure and communities, and reduce long-term losses from disasters, among others.



4 Encourage the states to have their own catastrophe model

a. State-specific catastrophe models will enable individual states to estimate their respective fiscal risks from natural hazards, providing a basis for budgeting pre-disaster mitigation measures and post-disaster response. It should be noted that although the PMLs for earthquakes are higher across India, not all states are prone to earthquakes. Some are prone to floods and cyclones. Thus, the central government must encourage states to develop their own catastrophe models to enable the central and state governments to allocate NDRF/SDRF resources efficiently and determine appropriate risk financing. It must be noted that catastrophe models will require a robust disaster database.

5 Strengthen the role of parametric insurance

a. The central government can further review existing disaster insurance schemes across states and promote the adoption of similar schemes in other states. For instance, the All-India Disaster Mitigation Institute (AIDMI) survey of the Afat Vimo microinsurance scheme highlighted that policyholders used their payouts to repair damaged homes and that the insurance coverage strengthened their resilience to extreme weather events. However, the same survey revealed limited awareness among the target community of the potential benefits of insurance and confusion about the claims process (Action on Climate Today 2016). On the other hand, the central government can consider expanding parametric insurance in Nagaland (Bindal et al. 2021). Parametric insurance will reduce the government's financial burden for post-disaster rehabilitation and encourage policyholders to adopt preparedness and mitigation measures. On the other hand, India can consider adopting the new parametric anticipatory insurance in Fiji, which incorporates the concept of Anticipatory Action (AA) (UNU-EHS and MCII n.d.). This approach involves taking proactive measures before extreme weather events to mitigate their impact. The insurance triggers are based on early warnings, such as wind speed and weather forecasts. This scheme includes two main components: (1) an anticipatory component with an *ex ante* payout of up to 20 percent of the total sum insured, determined by the predicted intensity of a tropical cyclone as measured by wind speed and pressure; and (2) a post-event payout of up to 80 percent of the sum insured, based on the actual wind speed recorded at the location. Any additional payout, if any, will be calculated once the final cyclone track data is published. Post-event payouts are adjusted based on the following conditions: 1) if the payout amount calculated from the final post-event data matches the anticipated payout, no additional payouts will be made to the policyholder after the event; 2) if the payout amount calculated based on the final post-event data is less than the anticipated payout, no refund will be required from the policyholder after the event; and 3) if the payout amount calculated from the final post-event data exceeds the anticipator payout, the balance will be paid to the policyholder after the event.

6 Explore the possibility of mandatory insurance for infrastructure

a In India, there is no mandatory insurance when purchasing a property, whether residential or commercial. Presently, less than 1 percent of residences are insured in India. Mandatory insurance for properties can be studied, such as the requirements for auto insurance as a loan protection measure, as banks and financial institutions require it when property loans are secured (Upadhyay 2023). The government may consider the possibility of requiring residential houses, businesses, or specific industries operating in defined disaster-prone areas– like businesses located in flood-prone areas - to have flood insurance coverage. Again, updated hazard maps will be essential to advancing mandatory affordable insurance coverage.

Pairing mandatory insurance, particularly for vulnerable and the poor, with existing subsidy schemes at the national and state level can reduce costs for the borrower. (An example could be combining PM Surya Ghar subsidy with solar roof top loans).

7 Explore the possibility of transferring risks

a Given its knowledge of critical infrastructure and vulnerabilities to hazards, India can consider risk-transfer mechanisms to mitigate fiscal imbalance. With identified critical infrastructure, updated hazard maps, and a robust disaster database, risks can be layered, and the state can decide which risks to retain or transfer.

- Low-risk but high-frequency events can be responded to by budget contingencies and dedicated reserve funds (e.g., NDRF and SDRF).
- Medium-risk or moderate-impact events may be addressed by expanded microinsurance and parametric agricultural coverage; an expeditious budget reallocation process; contingent credit lines or standby loan facilities from international donors, etc.
- High-risk but low-frequency catastrophic events may be covered by catastrophe bonds, insurance-linked securities, risk pooling, etc. (See annex for some examples from other countries and regions).

Relatedly, the country can initiate a study on developing a state-level insurance pool, such as the Philippine City Disaster Insurance Pool (PCDIP), a pioneering parametric insurance programme designed to provide city governments in the Philippines with rapid access to disaster relief funds post-event. PCDIP is a collective risk-pooling scheme where multiple cities purchase parametric insurance, managed by the Government Service Insurance System (GSIS) and supported by the Asian Development Bank (ADB) and private reinsurers (ADB 2018). In India, states can collaborate with other disaster-prone states to establish an insurance pool. This collaboration

aims to distribute the financial risks associated with disasters, allowing states to share both the costs and benefits of coverage. By leveraging economies of scale, such a pool could offer more affordable insurance premiums. This would ensure that participating states are better equipped to respond to and recover from disasters without overburdening their individual budgets. Annexed is a list of disaster risk financing mechanisms across countries and regions.

8 Public-private partnerships (PPPs) for infrastructure resilience

a Incorporating public-private partnership (PPP) models into infrastructure projects, including roads, power generation, and public transport, can effectively distribute financial risks between the government and private-sector entities. This collaboration not only harnesses private sector innovation and funding but also promotes the design and implementation of more robust, resilient infrastructure solutions. To further incentivize private investment, resilience-based incentives could be introduced for those who integrate disaster-resistant designs into their projects, thereby promoting a culture of safety and sustainability in construction.

9 Mainstream disaster and climate risks in development planning and investment decisions to minimize adverse disaster effects and impacts

a To institutionalize social and economic resilience, disaster risk management, and climate change impacts should be integrated into plans and investments of both the government and the private sector. Development plans and investments should take into account the building codes, land-use plans, and zoning regulations mentioned earlier. Furthermore, climate criteria should be mainstreamed into public investment, particularly those beyond certain investment threshold and in geographies located in climate sensitive zones. This will help promote climate resilient infrastructure and reduce fiscal burden in the long-term.

10 Continue to advocate for disaster preparedness and climate-friendly practices among the population to build resilience.

a Knowledge of disasters and climate risks, and community-based disaster risk management, will help local governments and communities prepare for and mitigate the adverse effects of natural hazards. This will lessen the fiscal risks associated with natural hazards.

11 Explore the establishment of a climate and disaster resilience fund

a To address persistent post-disaster financing gaps and strengthen *ex ante* financial preparedness, India can consider establishing a dedicated Climate and Disaster Resilience Fund that explicitly covers both climate-related and non-climate disaster risks. International experience demonstrates the value of such pre-disaster, ring-fenced financing mechanisms. For example, Australia's Disaster Ready Fund (DRF) (NEMA 2026) was established as a multi-year national programme to invest in disaster risk reduction and resilience. It shifts public spending from reactive relief efforts towards proactive preparedness. Drawing on this model, an Indian climate and disaster resilience fund could be designed to provide reliable, pre-arranged financing for risk reduction, resilience investments, and rapid early recovery. This fund would complement existing response-oriented instruments, such as the NDRF and SDRFs. The fund could be financed through a diverse mix of sources, including budgetary allocations, contributions from climate- and disaster-exposed sectors, support from international development partners, and innovative financing channels such as carbon markets or climate-linked instruments. By institutionalizing pre-disaster financing, the fund would reduce reliance on ad hoc post-event reallocations, limit fiscal volatility following major disasters, and support a strategic shift towards long-term resilience and fiscal sustainability amid increasing climate and disaster risks.

12 Study the creation of a sovereign catastrophe insurance pool

a India may want to consider developing a national sovereign catastrophe insurance mechanism, drawing inspiration from similar mechanisms in other countries, such as Spain's Consorcio de Compensación de Seguros (CCS) (Fitch Ratings 2024). This organization operates as a public reinsurance and compensation system for extraordinary risks. Under the Spanish model, coverage for catastrophic hazards—such as floods, earthquakes, windstorms, and other extreme events—is provided through a mandatory surcharge on standard insurance policies. The CCS centrally manages the losses. This approach has proven effective in closing insurance protection gaps, ensuring rapid claims settlement, and maintaining financial sustainability through pooled reserves.

A similar India-specific mechanism could be designed to complement existing public funding instruments by transferring a portion of sovereign disaster risk to a structured insurance pool. Recent multi-stakeholder workshops conducted by the National Disaster Management Authority (NDMA) (NDMA and Department of Financial Services 2024) in collaboration with the Department of Financial Services have explicitly explored disaster risk insurance, risk pooling, parametric insurance, and catastrophe bonds as viable instruments for strengthening India's disaster risk financing framework. These consultations highlighted the need for practical implementation pathways, institutional anchoring, and stronger engagement with the domestic insurance and reinsurance markets.

Building on these discussions, India could consider positioning GIC Re, the state-owned reinsurer, as the institutional anchor for such a sovereign catastrophe risk pool. GIC Re's balance sheet strength, reinsurance expertise, and existing role in public-sector risk coverage make it well placed to manage pooled disaster risks. It can also interface with global reinsurance markets and collaborate with domestic insurers on product design. Over time, this mechanism could enhance risk sharing, reduce fiscal volatility from large disasters, and provide a scalable platform for integrating insurance-based solutions into India's broader disaster risk financing strategy.

13 Leveraging international climate finance and green bonds

a Given the expected increase in the frequency and intensity of disasters due to climate change, India must take proactive steps to secure concessional global climate finance. Engaging with established international funding mechanisms, such as the Green Climate Fund (GCF), offers a valuable opportunity to secure the capital necessary for sustainable infrastructure initiatives and disaster-preparedness projects. In addition, issuing of green bonds by states in the domestic markets can serve as an innovative financing strategy to raise funds specifically targeted at enhancing resilience to environmental impacts while promoting sustainable development in the country. By leveraging these financial tools, India can better safeguard its infrastructure and communities against future climate-related challenges.





Chapter 8

Annexure



Annexure

Annex A: Disaster-related Insurance Schemes in Selected Countries

Sri Lanka[13]

Very recently, the global advisory, broking, and solutions company WTW (NASDAQ: WTW) has launched Asia's first 4-peril parametric insurance to protect Sri Lanka's shrimp farms against weather risks, marking a crucial turning point in Asia's aquaculture development. The unique solution was designed and implemented for Taprobane Seafood Group, Sri Lanka's largest seafood company, helping it meet a critical condition to secure $15 million in project financing from the Dutch entrepreneurial development bank FMO.

Shrimp farming is associated with a diverse range of risks and uncertainties, most prominently the exposure to weather risks across coastal regions where farms are traditionally located. To safeguard Taprobane against such vulnerabilities and unwind potential bottlenecks that constrain the injection of much-needed capital, WTW has structured the region's first 4-peril parametric insurance solution that covers four key weather risks: earthquake, typhoon, excess rainfall, and heat stress. This also enabled Taprobane Seafood Group to meet a critical condition for securing $15 million in project financing from the Dutch entrepreneurial development bank FMO.

The WTW also recently launched Nitrogen Risk Insurance, the world's first parametric insurance solution that allows sugarcane farmers in Queensland, Australia, to cover the risk of yield shortfall from reduced applications of nitrogen fertilizer on ratoon crops.

Thailand[14]

Since 2011, the Thailand Rice Disaster Relief Top-up Crop Insurance Scheme, which uses weather-index insurance for rice, has been available to farmers. The 'Remote-sensing based information and insurance for crops in emerging economies' project is a public-private partnership that is being implemented by the Swiss Agency for Development and Cooperation, the German Agency for International Cooperation, and others to reduce the vulnerability of smallholder rice farmers. In cooperation with the GeoInformatics and Space Technology Development Agency, the project integrates remote sensing technology with sophisticated crop-yield modelling to build a rice production monitoring system that provides accurate, timely information on rice areas, yields, and disaster-affected rice areas.

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[13] WTW, "WTW Launches Asia's First 4-Peril Parametric Insurance Solution to Unlock Financing for Aquaculture Development," press release, July 2023, https://www.wtwco.com/en-ph/news/2023/07/wtw-launches-asias-first-4-peril-parametric-insurance-solution-to-unlock-financing-for-aquaculture

[14] United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Disaster Risk Transfer Mechanisms: Issues and Considerations for the Asia-Pacific Region (Bangkok: UNESCAP, 2017).

India

Modified Area Crop Insurance Scheme of India (2010)

The National Agricultural Insurance Scheme (NAIS), established by the Government of India, is the world's largest crop insurance programme, covering approximately 25 million farmers, and is managed by the Agriculture Insurance Company of India (AICI). It provides insurance for food crops, oilseeds, and select commercial crops through an area-yield-based approach.[15] By comparing current crop yields with historical data, this indexed strategy provides indemnity payouts to farmers insured in specific locations when actual yields fall below historical levels. In addition to addressing issues with tiny landholdings, the plan lessens moral hazard and adverse selection. NAIS, however, depends on government contributions made after a disaster and on subsidized premiums. As a result, the government faces unlimited financial risk, and delays in claims settlement could lead to hardship for farmers. To enhance the programme's effectiveness and address these challenges, the government collaborated with AICI and sought World Bank technical assistance in 2005 to modify and improve insurance coverage.

India's First Weather Index Insurance Pilot by ICICI Lombard General Insurance Company (2003)

The first weather insurance product in India, and indeed in the developing world, was a rainfall insurance contract underwritten in 2003 by ICICI-Lombard General Insurance Company for groundnut and castor farmers of Hyderabad-based micro-finance institution BASIX's water user associations in the Mahabubnagar district of Andhra Pradesh. This innovative insurance programme provided coverage based on rainfall levels, helping farmers mitigate risks associated with unpredictable weather conditions. It serves as a key mechanism for disaster risk financing and insurance, offering innovative coverage based on weather indices. This pilot programme offers protection to farmers against adverse weather conditions, such as droughts or excessive rainfall, which can lead to crop losses and financial instability. By using weather indices to trigger payouts, the insurance scheme ensures timely compensation for farmers, helping them to mitigate the economic impact of climate-related disasters. Since then, weather-based crop insurance in India has evolved significantly, with various programmes and approaches to support farmers during adverse weather events. For instance, recent initiatives include heat-linked parametric insurance systems that provide a lifeline to women



[15] The World Bank, Disaster Risk Financing and Insurance Case Study – National Agricultural Insurance Scheme in India (Washington, DC: World Bank, 2011), https://www.farm-d.org/app/uploads/2019/05/DRFI_India_mNAIS_Jan11

in the informal sector in India.[16,17] This approach not only promotes resilience among agricultural communities but also helps stabilize livelihoods and fosters sustainable development in vulnerable regions. Additionally, by pioneering these initiatives, ICICI Lombard contributes to the growth of weather index insurance markets, paving the way for broader adoption and enhanced disaster risk management strategies across India.

Pradhan Mantri Fasal Bima Yojana (PMFBY) in India (2016)

A flagship agricultural insurance programme in India, the Pradhan Mantri Fasal Bima Yojana (PMFBY) uses an 'Area Approach Basis'[18] to provide farmers with reasonably priced crop insurance against inevitable natural risks from pre-sowing to post-harvest. The programme includes oilseeds, food crops, horticulture, and commercial crops. Farmers without institutional credit are not required to participate, but those who have bank loans are required to do so. The Ministry of Agriculture oversees the programme, which has been redesigned to expedite claim processing and payment, improve technology interventions, and give states greater flexibility in selecting risk covers and distributing premium subsidies. PMFBY aims to stabilize farm revenue, facilitate farmers' self-sufficiency in risk management, and encourage the adoption of contemporary farming techniques. The plan does not cover losses from riots, war, or nuclear hazards, but it does cover a variety of natural hazards and pests. It also aims to leverage smartphones and remote sensing technology to accelerate crop loss estimation.[19] In general, PMFBY aims to promote modern farming methods, maintain stable farmer incomes, encourage sustainable agricultural production, and ensure adequate financing for the agricultural sector to support competitiveness and food security. Through its comprehensive coverage and government support, PMFBY plays a significant role in mitigating the financial impact of agricultural disasters on farmers and promotes sustainable agricultural production in India.



[16] Daniel J. Clarke, Olivier Mahul, Kolli N. Rao, and N. Verma, Weather Based Crop Insurance in India, Policy Research Working Paper (Washington, DC: World Bank, 2012), https://documents1.worldbank.org/curated/en/693741468269445619/pdf/WPS5985

[17] Webpage of ICCI. Financial Inclusion. Financial Inclusion – ICICI Foundation

[18] Government of India, "Pradhan Mantri Fasal Bima Yojana (PMFBY)," 2020, https://www.mygov.in/campaigns/pmfby/

[19] Sandeep Kaur, Hem Raj, Harpreet Singh, and Vijay Kumar Chattu, "Crop Insurance Policies in India: An Empirical Analysis of Pradhan Mantri Fasal Bima Yojana," Risks 9 (2021): 191, https://doi.org/10.3390/risks9110191

Philippines[20]

In addition to multiple-peril crop insurance (MPCI), the country also has an all-peril property cover for public assets, provided by the Government Service Insurance System General-Insurance Group (GSIS-IG), a state-owned entity. The insurance covers all property in which the government has an interest (e.g., government offices, hospitals, schools, public markets).

Contingent credit for disasters is also in place, and insurance for public assets is in use. On 17 November 2021, the World Bank approved the Fourth Disaster Risk Management Development Policy Loan with a Catastrophe-Deferred Drawdown Option (CAT-DDO 4) of $500 million for the Government of the Philippines. Through a Cat DDO, the Philippines can access funds upon the declaration of a national State of Calamity due to an imminent or ongoing catastrophe or a declaration of a State of Public Health Emergency. The loan is available for three years and can be renewed for up to 15 years in total. Past Cat DDOs have been successfully disbursed to support the Philippines towards recovery in the aftermath of disasters such as Tropical Storm Washi (2011) and Tropical Cyclone Mangkut (2018), as well as the COVID-19 pandemic. The latest CAT-DDO 4 has also been disbursed after Typhoon Rai, which battered the country in December 2021. On 16 November 2023, a $ 500-million development policy loan for the country was approved by the WB/IBRD to finance the Philippines Disaster Risk Management and Climate Development Policy Loan with a Catastrophe Deferred Drawdown Option (DDO), which has set aside $ 500 million that the Philippine government can immediately draw upon in times of disasters and health crises, mitigating their impact on the economy. Funds may be disbursed when the President declares a State of Calamity in response to a disaster or public health emergency.

Catastrophe Bond.[21] In November 2019, the World Bank issued two tranches of cat bonds to capital market investors, providing the Philippines with insurance coverage of up to $225 million ($75 million for earthquakes and $150 million for tropical cyclones) for three years. The types of events that will trigger a payout are predefined in accordance with Philippine requirements. If and when a qualifying event occurs, the Philippines will issue a notice to an independent calculation agent to determine the insurance payouts. The World Bank will transfer the payouts to the Philippines as soon as a calculation report is available, within approximately one month for earthquake and five months for tropical cyclone events, without the need to assess real losses incurred by the country. The Philippines pays an insurance premium for the coverage, which the World Bank transfers to the cat bond investors. The premium is fixed for the life of the bond, removing the uncertainty of the cost.

[20] Department of Finance, Republic of the Philippines, 2023.

[21] World Bank, Case Study: The Philippines: Transferring the Cost of Severe Natural Disasters to Capital Markets (Washington, DC: World Bank, n.d.).

Mongolia[20]

In 2006, the Government of Mongolia, with assistance from the World Bank, implemented a pilot index-based insurance programme in three provinces to address livestock mortality. Shocks to animal well-being have devastating implications for the rural poor and the overall economy. The scheme combines self-insurance, market-based insurance, and social insurance. Herders pay a premium for a commercial risk product (Base Insurance Product) with specified trigger percentages for livestock mortality rates, whereas the Government finances and provides a social safety net product (Disaster Response Product). In addition, a syndicated pooling arrangement for insurance companies protects the domestic insurance market, as the government fully covers insured losses exceeding the pool's financial capacity under a reinsurance treaty with the World Bank.

Mexico[22]

Mexico has a considerable capacity for financial resilience and disaster response based on a wide range of financial instruments for risk management and risk transfer, among which several different insurance schemes and the following funds and trusts stand out:

Natural Disaster Fund (Fondo de Desastres Naturales, FONDEN), consisting of the Emergency Fund (Fondo para la Atención de Emergencias FONDEN), the Natural Disaster Fund Programme of the Branch of the Federal Budget, and the Natural Disaster Fund Trust. The Emergency Fund is a financial instrument for immediate and timely disaster response, providing relief, aid, and assistance to severely affected populations. Funds from FONDEN could be used for the rehabilitation and reconstruction of (i) public infrastructure at the three levels of government (federal, state, and municipal); (ii) low-income housing; and (iii) certain components of the natural environment (e.g., forestry, protected natural areas, rivers, and lagoons).

The Natural Disaster Prevention Fund (Fondo para la Prevención de Desastres Naturales, FOPREDEN) includes the Preventive Trust (Fideicomiso preventivo, FIPREDEN), which promotes and strengthens preventive actions for DRR, mitigates the effects of natural phenomena, and fosters DRR research. FIPREDEN provides resources to the agencies and federal and state units for unscheduled preventive actions.

[22] United Nations Development Programme (UNDP), Mexico: Country Case Study Report |How Law and Regulation Supports Disaster Risk Reduction (June 2014); World Bank, FONDEN: Mexico's Natural Disaster Fund – A Review (Washington, DC: World Bank, 2012).



The Fund for Rural Assistance to Climatic Contingencies (Fondo de Apoyo Rural por Contingencias Climatológicas) is operated by the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) within its Natural Disaster Assistance Programme for the agricultural, livestock, and fisheries sector (Programa Atención a Desastres Naturales en el Sector Agropecuario y Pesquero, CADENA) as one of the components of the Disaster Management Prevention Programme (Programa de Prevención y Manejo de Desastres). This fund aims to provide assistance, by means of insurance, to limit the negative effects caused by hazards on agriculture, livestock, aquaculture, and fisheries activities. The legal foundation for this fund is established under the Sustainable Rural Development Law, e.g., Art. 129, among others

The Fund for Rural Assistance to Climatic Contingencies (Fondo de Apoyo Rural por Contingencias Climatológicas) is operated by the Ministry of Agriculture, Livestock, Rural Development, Fisheries, and Food (SAGARPA) within its Natural Disaster Assistance Programme for the agricultural, livestock, and fisheries sector (Programa Atención a Desastres Naturales en el Sector Agropecuario y Pesquero, CADENA) as one of the components of the Disaster Management Prevention Programme (Programa de Prevención y Manejo de Desastres). This fund aims to provide assistance through insurance to limit the negative effects of geophysical and climate related disasters on agricultural, livestock, aquaculture, and fisheries activities. The legal foundation for this fund is established under the Sustainable Rural Development Law, including Art. 129.

The Federal Budget Law requires that an amount of no less than 0.4 percent of the annual federal budget be available to FONDEN, FOPREDEN, and the Agricultural Fund for Natural Disasters at the beginning of each fiscal year.

FONDEN resources are leveraged through market-based risk transfer instruments. Despite a stable annual budget appropriation, funding needs related to one or more disasters can cause a shortfall in any given year. To manage demand volatility on its resources, FONDEN may transfer risks through insurance and other risk-transfer mechanisms, such as catastrophe bonds. FONDEN is not, however, allowed to contract debt.

Mexico's First Sovereign Catastrophe Bond (2006)

The FONDEN uses a range of tools to assist local governments and organizations in responding to disasters, including risk-transfer programmes and reserve funds. To transfer Mexico's seismic risk to the global capital markets, FONDEN issued a $160 million catastrophe bond (CatMex) in 2006. Mexico decided to further diversify its coverage by pooling risks across multiple regions after the CatMex matured in 2009. Using the World Bank's recently formed MultiCat Programme, which assists sovereign and sub-sovereign entities in pooling multiple perils in multiple regions and lowering insurance costs, it issued a multiperil cat bond in October 2009.[23] With this bond, Mexico transferred a pool of disaster risk to the market for the first time; secured multi-year protection for the covered risks at a fixed price; and reduced potential pressure on public budgets. By leveraging the expertise of the insurance-linked securities market, Mexico effectively diversifies its risk and ensures access to timely funds for disaster management, reducing reliance on traditional post-disaster financing mechanisms.[24] This sovereign catastrophe bond not only enhances Mexico's financial resilience to disasters but also sets a precedent for other countries seeking innovative approaches to disaster risk financing and insurance.



[23] World Bank, A Case Study of Insuring Against Natural Disaster Risk in Mexico (Washington, DC: World Bank, 2015), https://documents1.worldbank.org/curated/en/170311468056076924/pdf/81172-REVISED-Mexico-MultiCatBond-2015

[24] World Bank, Disaster Risk Financing and Case Study – Mexico MultiCat Bond (Washington, DC: World Bank, 2013), https://openknowledge.worldbank.org/server/api/core/bitstreams/42f4a9ed-6f3d-5bbb-bb5b-e5c2cc6703ae/content

Component for the Attention of Natural Disasters (CADENA) Mexico (2003)

In Mexico, geophysical and climate change related disasters, particularly affecting agriculture, have increased in frequency and severity, with over 80 percent of economic losses occurring in the agricultural sector over the past two decades. Challenges include segmenting the farming sector, where small-scale farmers constitute a significant share but face barriers to accessing affordable insurance due to high transaction costs. To address this, the Mexican government has categorized farmers into three groups and developed tailored agricultural insurance programmes: commercial farmers who require insurance to finance, farmers able to pool risks and access credit, and small-scale, vulnerable farmers who lack access to credit or insurance. The CADENA Programme, launched in 2003, is a critical mechanism for disaster risk financing and insurance by providing formal, state-level parametric crop and livestock insurance solutions, primarily targeting small-scale, vulnerable farmers who lack access to traditional insurance or credit. It utilizes macro-level catastrophe climatic agricultural index products to provide social safety net coverage, thus replacing traditional post-disaster relief schemes with formal insurance solutions at the state level under the Ministry of Agriculture, Livestock, and Fisheries (SAGARPA).[25] By doing so, it replaces ad hoc post-disaster relief schemes with a structured insurance approach, mitigating the financial impacts of disasters on agriculture. This programme not only provides financial protection but also builds resilience among vulnerable farming communities, contributing to Mexico's overall disaster preparedness and response capabilities.

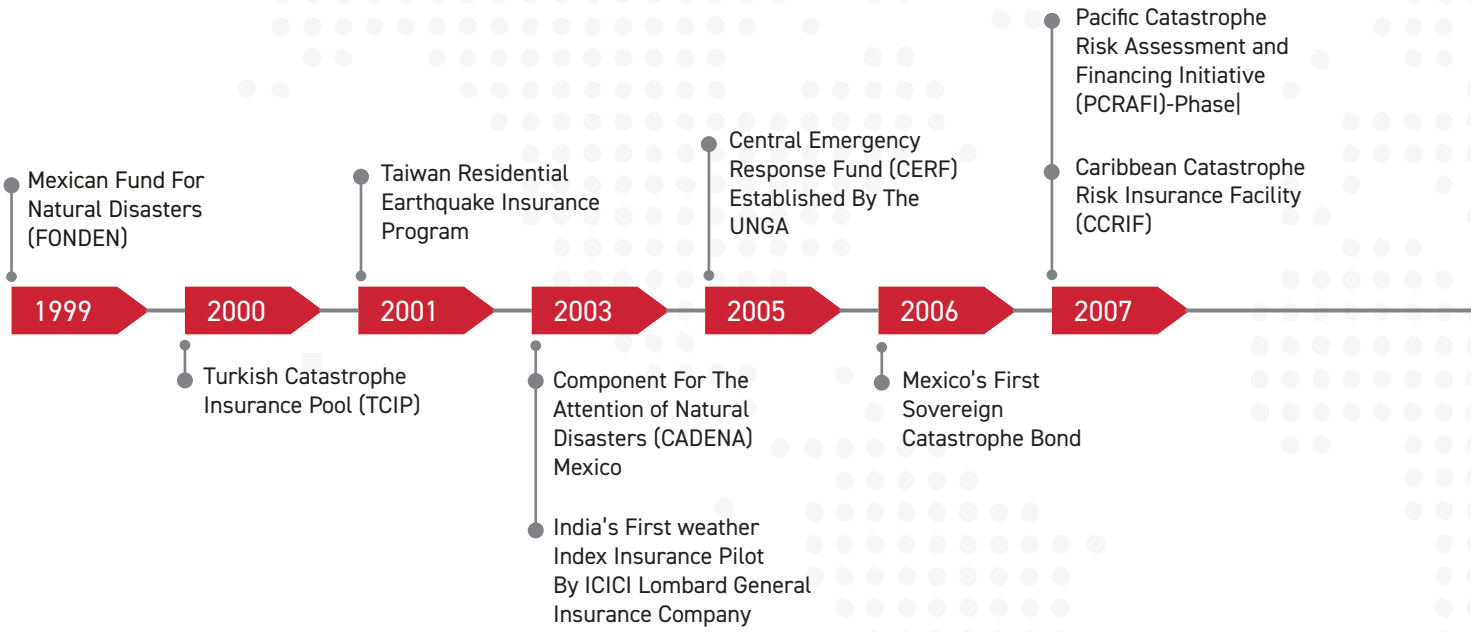
Mexico Indemnity-based Excess of Loss Insurance for Public Assets

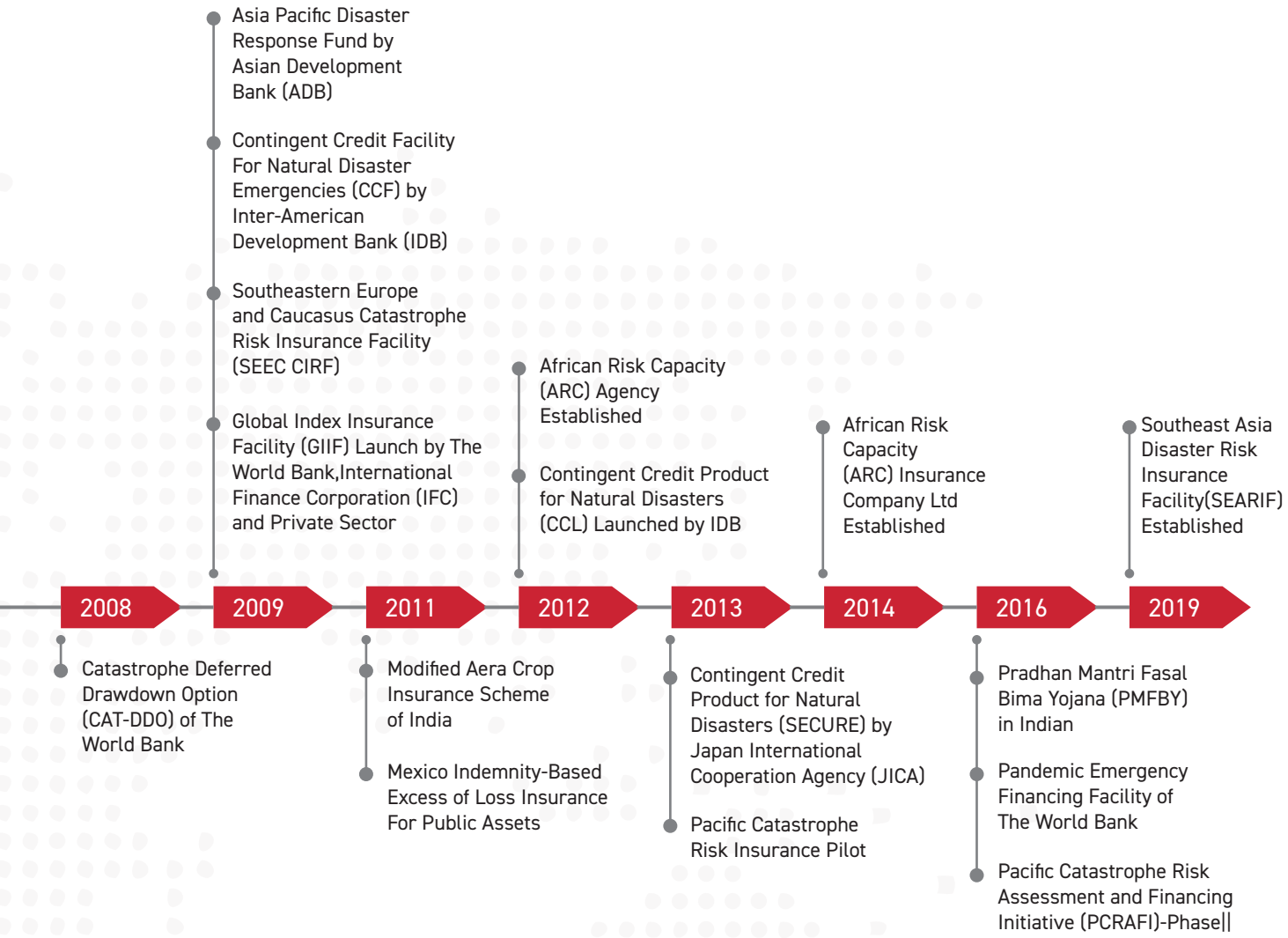
Mexico has established an innovative insurance scheme to reduce financial losses from catastrophes to public property. This programme evaluates fiscal risks for the government by quantifying both explicit and implicit contingent liabilities. It does this by fusing historical data with simulated-loss data. It has an excess-of-loss insurance component based on indemnity that activates when disaster-related claims reach a defined threshold. To increase resilience to disasters, Mexico's programme works in combination with risk-reduction initiatives, such as strengthening early warning systems, while also protecting the government budget.[26] The indemnity-based coverage kicks in when disaster-related costs exceed a certain threshold, shielding the government from excessive financial burdens. Moreover, the programme's integration with risk-reduction measures, such as early warning systems, enhances resilience to disasters, further emphasizing its role in comprehensive disaster risk management and financial protection.

[25] World Bank, Mexico Agriculture Insurance Market Review (Washington, DC: World Bank, 2013), https://documents1.worldbank.org/curated/pt/124521468287160777/pdf/881000BRI0P1300urance04Pager0Cadena

[26] World Bank, Quantify Contingent Liabilities Associated with Natural Disaster (Washington, DC: World Bank, 2013), https://documents1.worldbank.org/curated/en/672271467997574054/pdf/97977-BRI-Box391499B-PUBLIC-Short-Note-1-Risk-Assessment-04Nov2013


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24 HOURS


1999
Mexican Fund For Natural Disasters (FONDEN)
2000
Turkish Catastrophe Insurance Pool (TCIP)
2001
Taiwan Residential Earthquake Insurance Program
2003
Component For The Attention of Natural Disasters (CADENA) Mexico
India's First weather Index Insurance Pilot By ICICI Lombard General Insurance Company
2005
Central Emergency Response Fund (CERF) Established By The UNGA
2006
Mexico's First Sovereign Catastrophe Bond
2007
Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI)-Phase|
Caribbean Catastrophe Risk Insurance Facility (CCRIF)


2008
Catastrophe Deferred Drawdown Option (CAT-DDO) of The World Bank
2009
Asia Pacific Disaster Response Fund by Asian Development Bank (ADB)
Contingent Credit Facility For Natural Disaster Emergencies (CCF) by Inter-American Development Bank (IDB)
Southeastern Europe and Caucasus Catastrophe Risk Insurance Facility (SEEC CIRF)
Global Index Insurance Facility (GIIF) Launch by The World Bank,International Finance Corporation (IFC) and Private Sector
2011
Modified Aera Crop Insurance Scheme of India
Mexico Indemnity-Based Excess of Loss Insurance For Public Assets
2012
African Risk Capacity (ARC) Agency Established
Contingent Credit Product for Natural Disasters (CCL) Launched by IDB
2013
Contingent Credit Product for Natural Disasters (SECURE) by Japan International Cooperation Agency (JICA)
Pacific Catastrophe Risk Insurance Pilot
2014
African Risk Capacity (ARC) Insurance Company Ltd Established
2016
Pradhan Mantri Fasal Bima Yojana (PMFBY) in Indian
Pandemic Emergency Financing Facility of The World Bank
Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI)-Phase||
2019
Southeast Asia Disaster Risk Insurance Facility(SEARIF) Established

Türkiye

Turkish Catastrophe Insurance Pool (TCIP-2000)

The Turkish Catastrophe Insurance Pool (TCIP) serves as a key mechanism for disaster risk financing and insurance, providing coverage for disasters such as earthquakes, floods, and landslides. In 2000, the Turkish Government instituted a mandatory earthquake insurance system for all residential structures on registered urban land. This initiative aimed to shift the financial burden from the government to private insurers. To facilitate this transition, the World Bank provided crucial financial and technical support to establish the TCIP. The TCIP stands as a pioneering endeavour, becoming the world's first national catastrophe insurance pool among World Bank client countries. It offers standalone earthquake insurance coverage to homeowners and small- to medium-sized enterprises, marking a significant step towards disaster resilience and reducing the burden on government resources amid seismic risks. By transferring risk from individuals and businesses to a pooled system, TCIP contributes significantly to Turkey's disaster preparedness and recovery efforts, ensuring swift and effective responses in times of crisis while fostering long-term resilience and sustainability.[27]

Taiwan

Taiwan Residential Earthquake Insurance Program (2002)

The Taiwanese government established and promoted the Taiwan Residential Earthquake Insurance Program (TREIP) in response to the 1999 Chi-Chi Earthquake. TREIP has offered basic earthquake insurance since 1 April 2002. The program serves as a vital mechanism for disaster risk financing and insurance by providing earthquake coverage specifically for residential properties. Homeowners who experienced earthquake damage are able to get financial assistance to improve the stability of their properties. The government established the Taiwan Residential Earthquake Insurance Fund (TREIF) and designated it as the central organization of this statutory insurance program and the managing entity for the Risk Spreading Mechanism of Residential Earthquake Insurance to implement TREIF and provide homeowners with basic earthquake insurance protection.[28] This not only protects individual homeowners but also strengthens overall community resilience by encouraging earthquake-resistant construction practices and facilitating rapid recovery after seismic events. By pooling resources and spreading risk across a broad base, the program enhances Taiwan's disaster preparedness and response capabilities, ultimately fostering a more resilient society.

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[27] The World Bank. Disaster Risk Financing and Case Study – Turkish Catastrophe Insurance Pool. www.gfdrr.org/drfi

[28] Taiwan Residential Earthquake Insurance Fund (TREIF), "About TREIF," accessed February 11, 2026, https://www.treif.org.tw/.

Caribbean Catastrophe Risk Insurance Facility (CCRIF-2007)

The Caribbean Catastrophe Risk Insurance Facility, the world's first multi-country risk pool, was established in 2007 and pioneered parametric policies backed by both traditional and capital markets. To enable the introduction of new products and expansion into new geographic areas, the facility underwent a restructuring in 2014 and became a segregated portfolio company (SPC), now known as CCRIF SPC. It is registered, owned, and operated in the Caribbean. The CCRIF SPC helps governments in the Caribbean and Central America mitigate the financial impact of catastrophes by promptly supplying short-term liquidity when a policy is triggered. For tropical cyclones, earthquakes, excessive precipitation, the fisheries industry, and public utilities, CCRIF provides parametric insurance coverage. Through its parametric approach, CCRIF triggers payouts based on predetermined parameters such as wind speed or rainfall intensity, enabling swift and efficient response to disasters. By providing timely financial assistance, CCRIF helps member countries bridge the gap between immediate humanitarian needs and long-term recovery efforts, ultimately promoting resilience and sustainable development in the Caribbean. Moreover, CCRIF's risk pooling and reinsurance mechanisms enhance the affordability and availability of disaster insurance for small island states with limited resources, thus bolstering their capacity to manage and mitigate the impacts of disasters.[29]



[29] CCRIF SPC, The Annual Report of CCRIF SPC (2022–2023) (2023), https://www.ccrif.org/sites/default/files/publications/annualreports/CCRIF-SPC-Annual-Report-2022-2023_lowres

Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI-2007)

A regional initiative, the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) Program was launched in 2007 to strengthen the Pacific region's financial resilience to risks of disaster and climate change. The PCRAFI facility and the PCRAFI Technical Assistance Program are the two main pillars of Phase II, launched in April 2016. PCRAFI's holistic approach helps countries better understand and quantify their vulnerability to hazards by facilitating the development of risk assessment tools such as the Pacific Risk Information System (PacRIS). The Secretariat of the Pacific Community (SPC) is undertaking a project under the Technical Assistance Program to build on capacity for the Hazard and Exposure Database. Through in-country surveys, enhanced data-collection capabilities, and case studies highlighting the value of risk information, this project aims to update PacRIS data and eventually empower nations to independently manage their data and reduce future exposure.[30]

Catastrophe Deferred Drawdown Option (CAT-DDO) of the World Bank (2008)

An IBRD Flexible Loan product, the Drawdown Option (CAT-DDO), is designed to improve countries' crisis preparedness and responsiveness to catastrophes and public health emergencies. It offers swift disbursement contingency finance in the case of a disaster, providing liquidity up front while additional funding is raised. Approved prior to a disaster event, the Cat DDO provides immediate liquidity upon activation, serving as early budget support while additional funds are mobilized. By disbursing quickly and efficiently, the Cat DDO helps mitigate the financial impact of disasters, enabling governments to respond promptly to emergencies. This mechanism complements existing risk retention and transfer tools and provides early budget help as part of a larger risk management plan. The Disaster Risk Management Development Policy Loan, with a CAT DDO Project, aims to improve technical capacity, support policy reforms, and fortify Serbia's institutional and legal framework for managing the financial and physical effects of disasters. The CAT-DDO also helps Serbia's catastrophe insurance industry grow by offering financial safety nets and short-term funding for emergency response.[31]

[30] The World Bank, PCRAFI Catastrophe Risk Assessment Methodology (2013), https://reliefweb.int/report/world/pacific-catastrophe-risk-assessment-and-financing-initiative-pcrafi-risk-assessment

[31] The World Bank, A Product Note of IDA Catastrophe Deferred Drawdown (Cat-DDO) (2018), https://thedocs.worldbank.org/en/doc/563361507314948638-0340022017/original/productnotecatddoidaenglish2018

Asia Pacific Disaster Response Fund by Asian Development Bank (2009)

Established in 2009, the Asia Pacific Disaster Response Fund (APDRF) provides developing member countries (DMCs) of the Asian Development Bank (ADB) with loans that can be disbursed promptly for life-saving measures in the immediate aftermath of significant catastrophes. This funding helps DMCs augment relief from other donors during emergencies and help restore life-saving services to impacted individuals. This mechanism enhances countries' crisis-response capabilities, particularly when emergencies exceed their capacity to cover immediate expenses. Additionally, APDRF supports DMCs in mitigating the financial impacts of disasters by providing essential funding for urgent relief efforts, thereby contributing to the broader objectives of disaster risk management and resilience building in the Asia-Pacific region.[32] Assistance is eligible if certain emergency requirements are met, including a disaster, an official declaration of emergency beyond the nation's capacity to respond, and the UN humanitarian/resident coordinator (H/RC) confirming the scope and consequences of the disaster. The geographic scope of the damage, preliminary estimates of the number of dead and displaced, response capacity, and the cumulative impact of previous catastrophes on the country's ability to respond are among the factors that influence the size of the award.[33]

Contingent Credit Facility for Natural Disaster Emergencies (CCF) by Inter-American Development Bank (IDB) (2009)

One of the Inter-American Development Bank's (IDB) most important tools for assisting member nations in managing the financial risks of disasters is the Contingent Credit Facility for Natural Disaster Emergencies (CCF). It serves as a critical mechanism for disaster risk and financing insurance by providing member countries of the Inter-American Development Bank (IDB) with access to contingent loans following verified disaster events. It provides contingent loans repaid in the event of a catastrophic event, funding essential amenities and humanitarian relief. Countries need to have a Comprehensive Natural Disaster Risk Management Program (CDRMP) in place in order to be eligible for the CCF. The CCF, which incorporates parametric triggers based on preset event characteristics, symbolizes the IDB's approach toward proactive disaster risk management. It focuses on giving prompt financial support during the emergency phase of disasters.[34]

[32] Asian Development Bank, "Funds and Resources – Asia Pacific Disaster Response Fund," accessed February 11, 2026, https://www.adb.org/what-we-do/funds/asia-pacific-disaster-response-fund-apdrf

[33] NDC Partnership, "Asia Pacific Disaster Response Fund," accessed February 11, 2026, https://ndcpartnership.org/knowledge-portal/climate-funds-explorer/asia-pacific-disaster-response-fund-apdrf

[34] G. Collich, R. Rosillo, J. Martínez, D. J. Wald, and J. J. Durante, "Financial Risk Innovation: Development of Earthquake Parametric Triggers for Contingent Credit Instruments," in Natural Disasters and Climate Change, ed. J. Durante and R. Rosillo, SpringerBriefs in Economics (Cham: Springer, 2020), https://doi.org/10.1007/978-3-030-43708-4_1

South-eastern Europe and Caucasus Catastrophe Risk Insurance Facility (SEEC CRIF) (2009)

To address the lack of insurance coverage for natural hazards in Southeast Europe (SEE), a region highly vulnerable to disasters, Europa Reinsurance Facility Ltd. collaborated with the World Bank to implement the Southeastern Europe and Caucasus Catastrophe Risk Insurance Facility (CRIF). The project launches operations to provide small enterprises and homeowners with catastrophic insurance coverage through regional insurance providers, with the funding totalling more than $12 million.[35] The project's goals are to provide new insurance products for weather and catastrophe risk, streamline insurance procedures, and raise public awareness of disaster risk in the SEE member nations. The project comprises two components: participating in the SEEC CRIF, which supports countries in their efforts to join Europa Re, and receiving technical assistance from donors, delivered by Europa Re. This assistance includes risk mapping, product design, weather monitoring, and legislative reforms.[36] The project's ultimate goal is to make financial insurance against climate change and geological risks in the area more accessible to government organizations, businesses, farmers, and households.

Global Index Insurance Facility (GIIF) launched by the World Bank, International Finance Corporation (IFC), and the Private Sector (2009)

The European Union, Japan, and the Netherlands support the Global Index Insurance Facility (GIIF), managed by the World Bank Group, which aims to improve access to financing for microfinance institutions, small-scale farmers, and microentrepreneurs in developing nations. GIIF was established in 2009 with a primary focus on sub-Saharan Africa, the Caribbean, and the Asia-Pacific region. It uses index insurance solutions to manage catastrophic risks in agriculture, food security, and catastrophe risk reduction.[37] Through its initiatives, GIIF has enabled billions of dollars in funding, millions of contracts affecting tens of millions of people globally, and promoted resilience and financial inclusion in disadvantaged communities.[38] A crucial part of GIIF is index-based insurance, which eliminates the challenges of estimating individual losses by relying on predetermined indices to initiate payouts and enabling faster claims processing. Index-based insurance can help to mitigate catastrophic risks associated with agriculture, food security, and disaster risk reduction. This approach enables faster claims processing and ensures timely financial assistance to those affected by disasters, thereby promoting resilience and financial inclusion in vulnerable communities worldwide.

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[35] Global Environment Facility (GEF), "Regional - Southeastern Europe and Caucasus Catastrophe Risk Insurance Facility (CRIF)," 2012, https://www.thegef.org/newsroom/news/regional-southeastern-europe-and-caucasus-catastrophe-risk-insurance-facility-crif

[36] The World Bank, "Southeast Europe and Caucasus Catastrophe Risk Insurance Facility (Serbia and Macedonia)," 2024, https://projects.worldbank.org/en/projects-operations/project-detail/P110910

[37] The World Bank, "Global Index Insurance Facility – Overview," 2024, https://www.indexinsuranceforum.org/overview

[38] InsuResilience Global Partnership, "The Global Index Insurance Facility (GIIF)," 2017

African Risk Capacity Agency (ARC) (2012)

The African Risk Capacity (ARC) Group is comprised of ARC Agency, a Specialized Agency of the African Union founded in 2012, and ARC Insurance Company Limited (ARC Ltd), a hybrid mutual insurer and the commercial affiliate of the Group, founded in 2014. The ARC Group, comprising ARC Agency and ARC Ltd, was founded with the aim of improving the ability of African governments to plan, prepare, and respond to epidemics and catastrophes that are caused by extreme weather events. With an emphasis on inclusivity and gender equality, ARC offers member states facilities for risk pooling and transfer, early warning systems, capacity building, and risk pooling and transfer in order to increase resilience against catastrophes such as tropical cyclones and droughts. ARC seeks to establish pan-African climate response systems that transfer the cost of climate risks from governments to ARC, guaranteeing more prompt and equitable disaster aid by utilizing contemporary financing methods like risk pooling and transfer[39]. Through ARC, member states can access readily available response funds, reducing reliance on external aid and ensuring more timely, equitable disaster relief. By merging traditional disaster relief approaches with modern financial mechanisms such as risk pooling and transfer, ARC offers a sustainable African-led strategy for managing extreme climate risks and disease outbreaks, thereby promoting resilience and reducing the financial burden on governments and vulnerable populations.

Southeast Asia Disaster Risk Insurance Facility (SEADRIF) (2019)

Through SEADRIF, ASEAN nations can enhance their financial resilience to climate and catastrophe risks and access to finance options for disaster risk. SEADRIF was founded in Singapore as a trust to own a general insurance business. It provides financial and consulting services to enable rapid post-disaster funding, with an emphasis on flood risks in Myanmar, Cambodia, and the Lao PDR. It is also aiming to take its financial solutions to other ASEAN nations with middle-class incomes, such as Indonesia.[40] SEADRIF facilitates collaborative approaches to enhance preparedness for climate and disaster risks and helps member countries prevent catastrophes from becoming crises by combining resources and knowledge. With the COVID-19 pandemic adding to the stress of catastrophes and climate change intensifying extreme weather events, SEADRIF offers customized programs and products that address a range of needs across the ASEAN region at varying stages of development. Through programs like the ASEAN+3 Disaster Risk Financing Initiative, SEADRIF also provides a forum for information sharing, the development of technical solutions, and the investigation of insurance and other financial products.[41]

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[39] African Risk Capacity, "About," accessed February 11, 2026, https://www.arc.int/about

[40] The World Bank, "Southeast Asia Disaster Risk Insurance Facility (SEADRIF) Technical Briefing for Japanese Insurance Industry," 2019, https://www.worldbank.org/en/news/feature/2019/01/17/southeast-asia-disaster-risk-insurance-facility-seadrif-technical-briefing-for-japanese-insurance-industry-drmhubtokyo

[41] The World Bank, Project Information Document on Southeast Asia Disaster Risk Insurance Facility (SEADRIF): Strengthening Financial Resilience in Southeast Asia (2019), https://documents1.worldbank.org/curated/en/772221601306153071/pdf/Project-Information-Document-Southeast-Asia-Disaster-Risk-Insurance-Facility-SEADRIF-Strengthening-Financial-Resilience-in-Southeast-Asia-P170913.

Pandemic Emergency Financing Facility of the World Bank (2016)

The Pandemic Emergency Financing Facility (PEF)-a financing mechanism now officially closed, that was managed by the World Bank-was designed to provide an additional source of financing to help the world's poorest countries respond to cross-border, large-scale outbreaks. The PEF complemented the much larger role that IDA, the World Bank's fund for the poorest countries, and other international organizations and donors played in financing outbreak response. The PEF's design was unique in that it allowed payments to be sent directly through its cash window or, once triggered, through its insurance window to governments and pre-approved frontline responder organizations, such as UNICEF and WHO.[42]

Central Emergency Response Fund (CERF) established by the UNGA (2005)

The Central Emergency Response Fund (CERF), which was established by the United Nations General Assembly (UNGA) in 2005 as the United Nations global emergency response fund, enables humanitarian actors to provide life-saving assistance to the most vulnerable people at the most appropriate time and location. CERF funding enables UN agencies and partners to jointly initiate relief efforts in emerging or escalating crises before other funding sources become available[43]. It serves as a crucial mechanism for disaster risk financing and insurance by providing rapid, predictable funding for humanitarian response to sudden-onset emergencies. Additionally, CERF is a strategic tool for addressing significant budget gaps in emergencies that receive insufficient funding. Furthermore, the flexible financing mechanism of CERF allows for quick allocation of resources based on assessed needs, enhancing the effectiveness and efficiency of humanitarian interventions in disaster-affected areas[44]. Through its proactive financing of emergency response, CERF plays a vital role in strengthening global disaster preparedness and resilience, ultimately contributing to more effective disaster risk management worldwide.

[42]The World Bank and World Health Organization, Report on Pandemic Emergency Financing Facility (PEF) Framework (2022), https://thedocs.worldbank.org/en/doc/24dce6fdf04a1313a07f7c24f539f4c7-0240012017/pandemic-emergency-financing-facility-pef-framework

[43] United Nations Office for the Coordination of Humanitarian Affairs (OCHA), "Central Emergency Response Fund," accessed February 11, 2026, https://cerf.un.org/

[44] United Nations, Annual Report of CERF (2022), https://cerf.un.org/sites/default/files/resources/CERF_ARR_2022_20230904

Annex B: Various Risk Financing Mechanisms, their Usage, Advantages, and Disadvantages[45]

1 Disaster Insurance

Definition

Insurance is a financial transaction by which the insured, a physical or legal person, transfers to an insurer its hazard risk in exchange of a payment (insurance premium). Providers of insurance are licensed and supervised insurance companies, captive insurers, and insurance pools, which are entities exclusively dedicated to the insurance activity. In some jurisdictions, non-licensed insurance activity exists. Depending on how this activity is controlled, it could result in an inability to fulfil the claim payment after a disaster due to insufficient funds by the entity acting as an unlicensed insurer.

Main usage

Major disaster risk refers to a low-frequency, high-severity event (earthquake, flood, cyclone, tsunami, drought, etc.). Although exposure and vulnerability to these events can be reduced, significant residual risk may remain, making insurance a viable risk management strategy.

Advantages

- Agreed well-defined benefit in case of a disaster event.
- Coverage can be purchased based on individual needs and risk appetite.
- Cost of coverage can be based on individual levels of risk.
- Insurers help with risk reduction and risk assessment.
- Disaster risk managed by professionals.
- Predictable costs for the protection in the form of a fixed premium.

Disadvantages

- Laypersons may find policies hard to understand because the policy wording contains legal language.
- Key risks or those risks that are seen as more important by consumers may be excluded.
- Policies often include a large combined monetary and percentage deductible on each and every loss, negating or diminishing the benefits of insurance.
- The claim ceiling may be insufficient to replace the insured property to the same pecuniary state enjoyed before the disaster event.
- Benefits are not clearly perceived as disaster events occur infrequently, so for many years the premium is paid, but no tangible benefit is obtained.
- Claim settlement can be burdensome.

[42]Asian Development Bank (ADB), Assessing the Enabling Environment for Disaster Risk Financing: A Country Diagnostics Tool Kit (Manila: Asian Development Bank, 2020).

Preconditions

- Disaster risk awareness.
- Enabling government policy with respect to the development of disaster insurance instruments, potentially including mandatory insurance cover and tax benefits on the premium payments.
- Disaster risk product availability and affordability, including products for corporates, individual households, and low-income populations.
- Credibility of the insurance sector, including with regard to the regulatory environment, the solvency and reputation of the insurance markets, and the availability of support from professionals such as actuaries, risk assessors, auditors, brokers, and loss adjusters.
- Complementary social protection solutions, allowing low-income populations to enjoy social protection or support in the acquisition of insurance, while avoiding the crowding out of insurance solutions for people who can afford premiums.
- No unlicensed competition. Insurance credibility and resilient insurance providers are important and can only be achieved if all insurance providers are licensed and supervised by the insurance regulator.

2 Disaster Reinsurance

Definition

Reinsurance is a financial transaction by which disaster risk and other insured risks assumed by an insurer in the original insurance policy are transferred (ceded) from the insurance company (cedent) to a reinsurance company (reinsurer) in exchange for a payment (reinsurance premium). Providers of reinsurance are professional reinsurers, which are entities exclusively dedicated to the activity of reinsurance. In most jurisdictions, however, insurance companies are also allowed to participate in reinsurance (Wehrhahn 2009). Reinsurers can effectively assume large amounts of disaster risk by diversifying across the world and maintaining substantial capital to support those risks.

Main usage

Major disaster risk refers to a low-frequency, high-severity event (earthquake, floods, cyclone, tsunami, drought, etc.). This risk is difficult to diversify at the primary insurer level. Hence, without additional risk-transfer options, insurers would not be economically able to accept this type of risk on their own. Insurers mitigate disaster risk on balance sheets by entering into reinsurance agreements.

Advantages

- Geographic diversification of disaster risks when using global reinsurance.
- Increased underwriting capacity of the insurance sector. By ceding part of the risk, insurers can technically accept higher volumes of disaster risk. This is particularly important for disaster insurance, as the scale of exposure of an insurance company can be very large.
- Risk-based pricing of premiums as reinsurers have access to disaster risk.
- Reduction in the volatility of insurance company financials and protection of ceding companies' balance sheets.
- More predictability in profit and shareholder returns.

Disadvantages

- Insurers transfer the underwriting risk but assume credit risk. Proper credit risk analysis of the reinsurer is critical.
- Premium pricing depends to some extent on global capacity available and could become prohibitive in the event of a quick succession of extreme events.
- Terms on the risks reinsured are dictated by the reinsurer and could be different from the original insurance policy. Thus, the original risk is only partially transferred, leaving insurers with substantial risk on their books, even after reinsurance.
- Payment of claims could be a lengthy process, affecting the cash flows of the ceding company.
- Reinsurers may include 'event limits' on their treaties, thus exposing ceding companies to the possibility of having to take back the unreinsured portion of the claims.
- Possibility of exhausting the nonproportional excess of loss reinsurance protection after a disaster without reinstatement of the cover, thus leaving insurers unprotected against subsequent disaster events in the same country or region.

Preconditions

- Sound supervision of the insurance and reinsurance markets to guarantee effective products and timely payments of claims.
- Availability of international reinsurers interested in acting in the given country.
- Availability of data and risk maps.
- Minimum credit rating of the reinsurers by reputed rating agencies such as AM Best, Fitch, and Standard & Poor's Global Ratings.
- Appropriate supervision of reinsurance brokers acting in the region/country.

3 Insurance-Linked Securities

Definition

Insurance-linked securities (ILS) are investment instruments that transform insurance risk into transparent, tradable capital-market products. Investors take on insurance risk in exchange for a higher rate of return as compared with other securities free of that risk. The insurance risk materializes when a predefined disaster event occurs, such as an earthquake or tropical cyclone of a certain intensity. ILS include categories of vehicles such as catastrophe bonds, longevity or mortality bonds, fully collateralized reinsurance agreements, and industry loss warranties.

Main usage

Catastrophe or cat bonds and other types of ILS are usually issued in order to provide (re)insurance protection to insurers, reinsurers, governments, and corporations. ILS offers protection from new pools of capital separate from traditional reinsurers, such as hedge funds and pension funds. Investor capital provides collateralized cover. The capital is held in a segregated collateral account with dedicated funds available to make a payment should a qualifying event occur. This virtually eliminates the credit risk inherent in traditional (re)insurance (Swiss Re 2012).

Advantages

- Immediate access to funds once the trigger event has been confirmed.
- Limited concern about counterparty credit in the event of an extremely large event, as the claim amount is fully collateralized.
- Predictable budgetary costs for the issuer of the bonds.
- Tailor-made triggers to cover individual disaster risk contexts.
- A diversified source of disaster risk financing, which is especially beneficial when there is a shortage of retrocession capacity or hard pricing cycles in traditional reinsurance markets.
- Multiyear pricing stability (terms of 3–5 years are typical for cat bonds).
- For investors, a source of investment that is uncorrelated to broader cycles in financial market performance, resulting in a higher degree of portfolio diversification.

Disadvantages

- Complexity of the product. Securities are already complex, and adding triggers tied to underwriting risks further complicates the instrument's structure.
- Costs may be relatively high if the volume of issuance is small. Transaction size ranges from a minimum of around $100 million to $750 million or $1 billion (Swiss Re 2012).
- Basis risk exists as the triggers might not be totally correlated with the actual loss suffered.
- Investor appetite may differ from the desired triggers.
- Triggers may be difficult to assess.

Preconditions

- Sophisticated securities markets that are able to issue ILS.
- Sophisticated investors looking to diversify their investments away from traditional forms of market risk.
- Transparent product structures.
- Transparent and robust disaster risk models.
- Clearly defined triggers.
- An enabling government policy including tax benefits for ILS investors, regulations that allow insurers and reinsurers to use ILS for capital relief, etc.
- Attractive returns for investors in the ILS markets.
- Credibility of the securities sector, including with regard to the associated regulatory environment, credibility and reputation of sponsors, and the availability of professionals such as broker-dealers, rating agencies, actuaries, and auditors.

4 Agricultural Indemnity Insurance

Definition

Agricultural indemnity insurance is a type of insurance that indemnifies the insured person against pure agricultural loss (i.e., crop or livestock). The loss is verified by a loss assessment process. The insured person could be the farmer or farmer group or an agricultural lender whose delinquency risks depend on the outcome of agricultural output.

The following forms of agricultural indemnity insurance products are presently popular:

1. Single-risk insurance: Covers against one peril or risk (e.g., drought).
2. Combined (peril) insurance: Covers a combination of several risks (two or more risks, mostly with hail as basic cover). In some countries, this type of insurance is also called multi-risk insurance.
3. Yield insurance: Provides a yield guarantee, based on regional average yield or on individual historic yield, covering the main risks affecting yield (e.g., drought). In some countries (e.g., the United States), this type is also called combined or multiperil insurance.
4. Revenue insurance: Combines yield and price risks coverage in a single insurance product. It can be product-specific or the whole farm.
5. Farm-income protection insurance: Covers losses to future income (e.g., future droughts) based on investments in long-term production, thereby reducing reliance on government assistance in times of need and building farmers' business resilience. It includes yield and price risks and accounts for production costs. Usually, this type of insurance is not product-specific; instead, it covers whole-farm income.
6. Whole-farm insurance: Consists of a combination of guarantees for different agricultural types of production on a farm. Depending on the coverage selected, the guarantees can be whole-farm yield, revenue, or income insurance (EU 2008).

Main usage

Agricultural indemnity insurance provides coverage to farmers and agricultural lenders against losses of crop or livestock. When purchased by agricultural lenders, it can also increase their risk appetite to lend to farmers who are not otherwise creditworthy and to offer better terms than for uninsured risks.

Advantages

- **Low basis risk:** Indemnity insurance in comparison with index insurance has low basis risk (i.e., the claim amount nearly matches the actual loss suffered).
- **Less data requirement:** Indemnity insurance requires less data, as compared with index insurance, for the design and development of products.
- **Reasonably transparent verification processes:** Losses are verified on the ground, usually in the presence of the insured farmers, although entailing some level of subjectivity.
- **Transparent settlements:** Payouts are based on the scale of damage and losses experienced, making settlements easy to understand and communicate.

Disadvantages

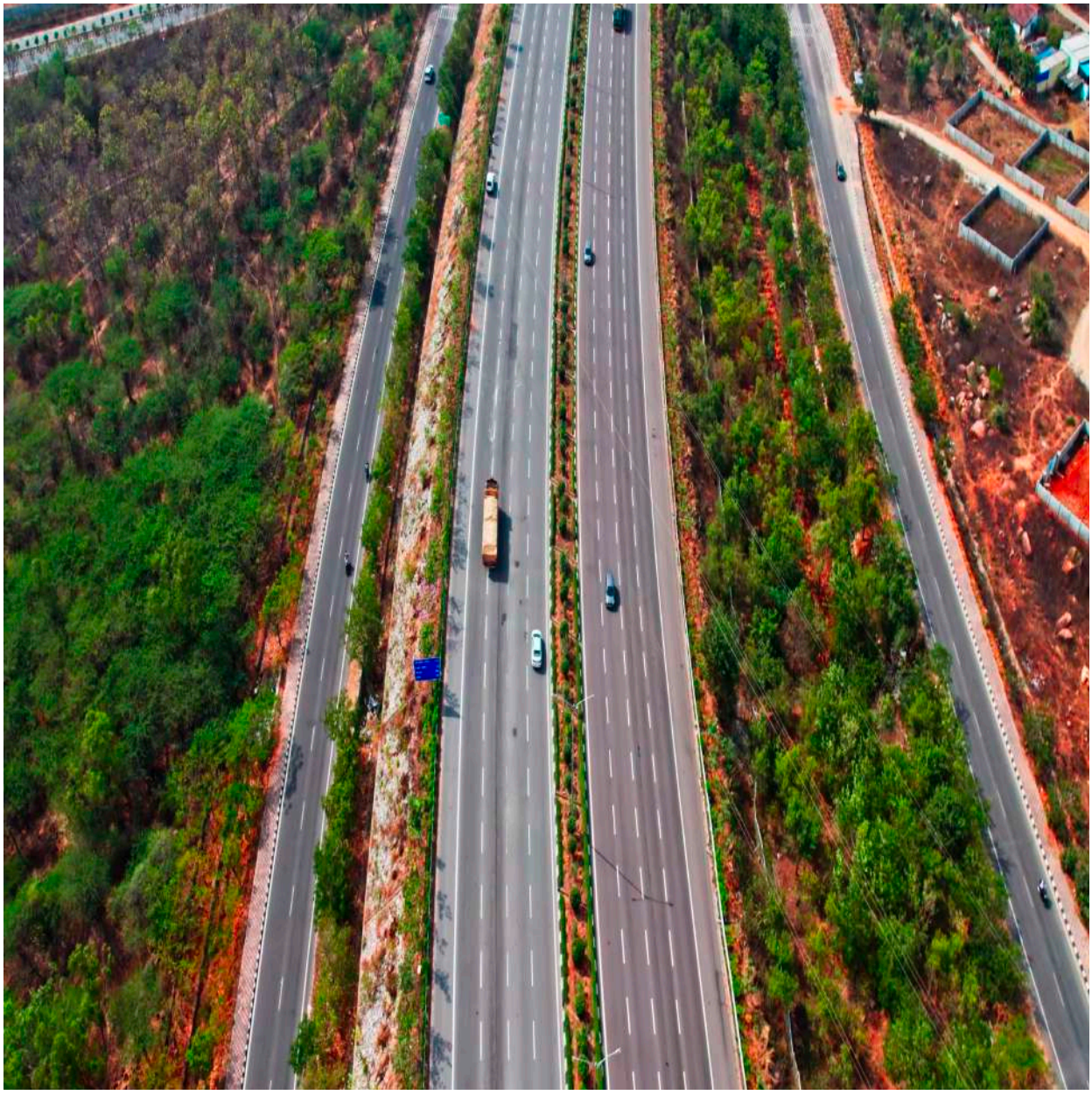
- **Onerous assessment processes:** As a claim is paid after assessing each loss, the loss assessment process can be onerous and costly. However, modern, affordable technology can reduce loss assessment time, keeping costs in check. Technology-based tools can also provide corroborative information to reinforce human loss assessment activities.
- **Costly assessments:** The onerous loss assessment process implies high assessment costs.
- **High risk of adverse selection and moral hazard:** Claim payments often rely on crop-cutting experiments, leaving room for manipulation. Adverse selection (i.e., the purchase of insurance by farmers who are more likely to experience claims) is more likely with indemnity than with index-based insurance. Moral hazard (i.e., farmers acting in a manner that leads to greater chances of the claim becoming payable) is also more likely with indemnity than with index-based insurance.

Preconditions

- **Historical loss, modelled loss, and exposure data:** This information is required for several aspects of the product design, product evaluation, and product pricing processes. Insurance can work for risks with low frequency and high values, but the product needs to be designed so that risks with higher frequency and lower values are not transferred to the insurer; instead, they are retained—and ideally reduced—through farmers' risk-reduction efforts.
- **Subject specialists:** Worthy products are usually developed with assistance from subject specialists. It is therefore important to ensure that the product development team has access to the required expertise, either internally or externally (e.g., agronomists, modelers, underwriters, and actuaries).
- **Distribution channels:** Efficient distribution channels lead to low administrative costs for underwriting and claim settlement. The insurer may have a captive distribution channel (e.g., its own sales force to distribute credit-linked insurance for agricultural risks). The insurance product's sales process often needs to be embedded within the insured's core business activities.

- **Availability of reinsurance:** Crop and livestock claims depend upon weather and other natural hazards, which can affect the entire region of coverage in a relatively short time span. This can result in large, often covariate, losses for the insurer increase capital requirements to demonstrate solvency. Reinsurers can accept such risks by covering geographically diverse regions over long periods of time within their already diversified lines of business. Therefore, reinsurance capacity is necessary for agricultural insurance, which inherently faces large, covariate risks.

- **Regulatory support:** Regulation can support agricultural index-based insurance in many ways: (i) by setting lighter solvency requirements due to the extremely short tailed losses, if that is not the case under the existing solvency requirements; (ii) by providing a prompt redress mechanism on claim settlement; or (iii) by setting up data infrastructure and coordinating investment in data as a public good.



5 Agricultural Index and Parametric Insurance

Definition

Agricultural parametric insurance is a form of insurance that *ex ante* agrees to make a payment upon the occurrence of a trigger observation or event linked to the loss, rather than indemnifying the pure agricultural loss (i.e., crop or livestock). The trigger observation could be a decrease in average yield or prices in a predefined area—area yield index insurance or a trigger event based on weather-based indexes, satellite images, and so on. In developing such products, it is necessary to understand the thin dividing line between parametric insurance and index-based insurance. A parametric insurance product typically works on a binary parameter with only two possible outcomes (e.g., death or contracting a critical illness). In such cases, either a full payout or no payout is made as only two outcomes are possible. In contrast, index-based insurance is offered based on parameters that typically yield multiple outcomes (e.g., wind velocity and precipitation levels) and can result in a graded scale of payouts. In such cases, claims are often linked to the trigger in a gradual manner (e.g., the farther above the observation from the trigger, the higher the claim payout) until a pre-agreed ceiling is reached. The insured person could be the farmer or farmer group or lender whose delinquency risks depend on the outcome of agricultural output.

The following forms of agricultural indemnity insurance products are presently popular:

1. Area yield index insurance: Indemnities are computed from the decrease in the average yield over an area without ascertaining the crop output of individual farmers.
2. Area revenue index insurance: Indemnities are computed from the decrease in the production of the average yields and prices in an area (EU 2008), without ascertaining crop output and prices of individual farmers.
3. Indirect index insurance: Indemnities are based on indexes of yields or vegetation that are computed from weather-based indexes, satellite images, and others (EU 2008).

Main usage

Agricultural parametric insurance provides security for farmers and agricultural lenders by eliminating subjectivity in loss verification and reducing claim settlement time. When purchased by agricultural lenders, it can also increase their appetite to lend to farmers who are not otherwise creditworthy and to offer better terms.

Advantages

- **Low moral hazard:** Since the amount of payment is unaffected by the loss experienced, insured farmers (both crop and livestock) have an incentive to act in a manner that minimizes their losses, reducing issues of moral hazard.
- **Low adverse selection problem:** Similarly, parametric insurance reduces the risk of adverse selection as payouts are based on widely available information, rather than on individual loss experience and related risk about which insurance companies may not have full information.
- **Easier loss assessment:** Since the claim payment is dependent on a trigger, efforts in assessing losses (e.g., deploying loss assessors on-site and seeking inputs) are substantially minimized.
- **Prompt claim settlement:** As actual loss assessment is not needed, claim settlement can be prompt after reading off the index.

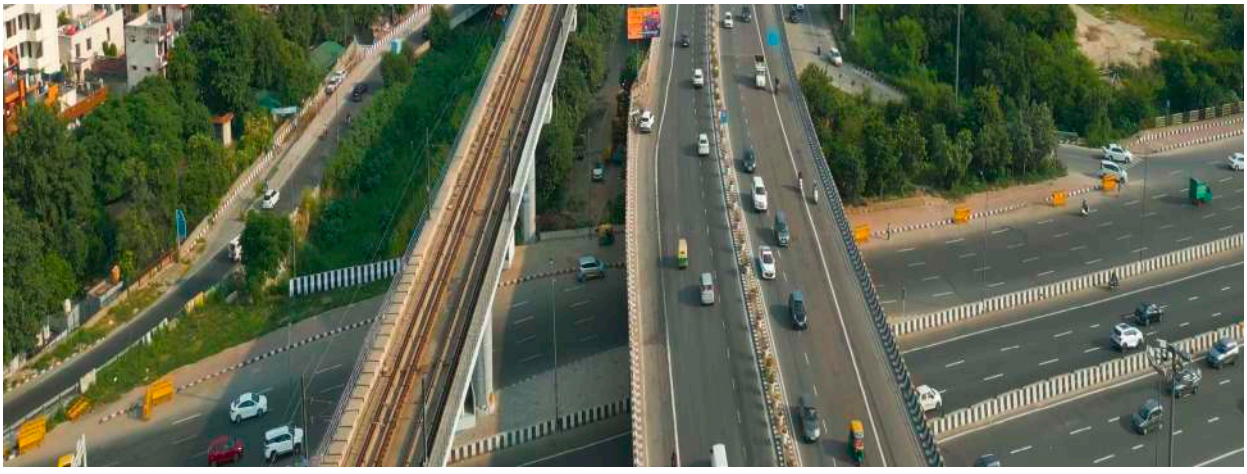
Disadvantages

- **Basis risk:** Index-based insurance, unlike indemnity insurance, carries 'basis risk'. This is the risk that the index measurements that trigger the insurance payout will not match the actual loss experienced. The payout could be less or more than the expected loss. Basis risk can reduce customer satisfaction and affect the continuity of an insurance program.
- **Model risk:** If robust modelling tools and techniques are not used, the loss frequency results may be incorrect, leading to inappropriate pricing and, in turn, directly affecting client satisfaction and the uptake of insurance.
- **Substantial data requirements:** Rate making and trigger definition require a large amount of weather and crop yield data. Insufficient data can lead to incorrect decisions on rate making and product design.
- **Complexity:** Farmers may face difficulties in comprehending the linkage between triggers and losses and the overall benefits of index-based insurance.
- **High product development costs:** Subject experts and data infrastructure are required for the design of parametric insurance, increasing product development costs.

Preconditions

- **Historical and modelled weather data:** This information is required for several stages of product design, evaluation, and pricing. If such information is not available, designing a robust product will not be feasible.
- **Subject experts:** Valuable products are usually designed with assistance from subject specialists. It is important to make sure that the product development team is multiskilled (e.g., in crop agronomy and statistical modelling) and has the necessary experience and expertise to develop the required products.
- **Historical and modelled loss data:** Especially for area yield index insurance, historical and modelled loss data are essential in pricing the product and determining the trigger.

- Real-time hazard data: Real-time hazard data are required to provide prompt payouts and maintain customer satisfaction.
- **Product design capabilities:** High-quality product design capabilities must be available to the insurer, either internally (in the long run) or externally (in the short run).
- **Regulatory and supervisory support:** Regulation can support agricultural index-based insurance in many ways:
  - by setting lighter solvency requirements due to the extremely short-tailed losses, if it is not the case in the existing regulations.
  - by recognizing index insurance, which could otherwise be argued as a 'derivative' product.
  - by setting up data infrastructure and coordinating investment in data as a public good; or
  - by setting up a supervisory mechanism that emphasizes the education of farmers on parametric products.
- **Distribution channels:** Proper distribution channels are required to help ensure low administrative costs for underwriting and claim settlement.
- **Availability of reinsurance:** Index insurance is normally used to transfer covariant risks that can affect a whole country or region at the same time, necessitating access of insurers to sufficient reinsurance capacity.
- **Weather infrastructure:** A sufficient network of tamper-proof weather stations and satellite imaging infrastructure is required to capture data regularly and accurately.
- **Animal mortality rates:** In the case of mortality index-based livestock insurance, historical animal mortality rates (including exposure and death events) by species, time, and geography are necessary.



6 Sovereign Parametric Insurance

Definition

Like any parametric insurance, sovereign parametric insurance *ex ante* agrees to make a payment upon the occurrence of a trigger observation or an event linked to the loss, rather than indemnifying the pure loss. It may be purchased by the government of a sovereign state and works on the usual insurance principles of premium payment to cover risks. Trigger observations can be specified intensities of natural hazards at a specified location (e.g., rainfall level, wind speed, seismic shocks measured on the Richter scale) as measured by an independent agency. Claim payouts could be linear (i.e., gradually increasing claims paid as the actual observation moves beyond the parametric trigger) or categorical (i.e., payment of a fixed sum on the breaching of the defined parametric trigger).

Main usage

Parametric insurance may be used to provide security to a country's fiscal position while reducing the element of subjectivity in loss verification and time to settle claims. It also reduces the post-disaster fiscal stress on the insured country, hence smoothing government spending. Parametric cover is suitable for low-frequency, high-severity events.

Advantages

- **Fiscal support:** Sovereign insurance reduces potential post-disaster budget reallocations, which in turn may derail achievement of a government's development goals.
- **Easier loss assessment:** Since the claim payment is dependent on a trigger, efforts in assessing losses are substantially minimized, and objectivity is increased.
- **Prompt claim settlement:** As actual loss assessment is not needed, claim settlement can be very prompt, occurring within just 2–3 weeks following an event.
- **Low operating cost:** Operating costs are low relative to traditional insurance products due to the simplicity of sales and loss adjustment, the lack of need to classify policyholders according to their risk exposure, and the lack of asymmetric information.

Disadvantages

- **Basis risk:** Index-based insurance, unlike indemnity insurance, carries 'basis risk'. This is the risk that the index measurements that trigger the insurance payout will not match the actual loss experienced. The payout could be less or more than the expected loss.
- **Model risk:** If robust modelling tools and techniques are not used, the frequency results can be incorrect, leading to inappropriate pricing and, in turn, directly affecting client satisfaction and the uptake of insurance.
- **High start-up costs:** Despite low operating costs, index insurance can have high start-up costs, especially in the absence of appropriate weather data and skilled meteorological expertise. A country's readiness to purchase parametric insurance coverage depends in part on its existing infrastructure, including asset inventories, meteorological data,

- **Low moral hazard:** As the amount for payouts is unaffected by the loss experienced, governments have an incentive to act in a manner that minimizes losses, reducing issues of moral hazard.

hazard maps, exposure data, vulnerability analyses, historical disaster data, and disaster risk models.

- **Data requirements:** Rate making and trigger definition require a large amount of data, such as on exposed assets (including public assets), past and modelled hazard events, and weather. The absence of data can lead to incorrect decisions on rate making and product design.

Preconditions

- **Understanding of disaster risk:** Parametric cover is best applicable to very low frequency, high-severity events.
- **Data infrastructure:** Weather and seismology-related information is required for several stages of product design, evaluation, pricing, and implementation. Information should be capable of independent verification using different tools. For example, satellite images can complement a primary weather station's information regarding precipitation. If this type of information is not available, it may not be possible to design an appropriate product.
- **Subject experts:** Valuable products are usually designed with assistance from subject specialists. It is important to ensure the product development team is multiskilled and has the required experience and expertise. Often, there is a need to involve reinsurance companies interested in underwriting the cover to provide domain expertise.
- **Historical and modelled loss data:** Historical and modelled loss data are essential in pricing the product as well as in defining the trigger. Insufficient or inappropriate data could lead to coverage gaps or other serious product-related issues.
- **Real-time hazard data:** In the absence of real-time data, it is difficult to gauge the amount of claim payment in a timely manner.
- **Frequency and accuracy of recording data:** Weather stations and satellite imaging infrastructure need to capture data regularly and accurately, and be highly resistant to any form of tampering. This type of infrastructure is critical to assessing whether a particular area has breached the trigger.

7 Insurance Pool

Definition

An insurance pool is a multi-member risk-sharing arrangement in which organizations (often primary underwriters) pool their funds to finance exposure, liability, risk, or some combination of the three. Pools can have layers of coverage, such as insurance, excess insurance, and different deductibles for different members.

Main usage

An insurance pool can create capacity at multiple dimensions: supply of insurance for business lines that face high risks from unfavourable outcomes, underwriting of large risks by pool members, technical capacity for development of complex insurance products, advice and information gathering for loss assessment, stability of underwriting results, and reduction of the impact of single and large risks.

Advantages

Designing an insurance pool should consider the following factors (ADB 2019d):

- **Product design:** Undertaking product design and providing support on an ongoing basis is more efficient when a centralized pool gathers information.
- **Information gathering:** Being a repository of losses, the pool is able to undertake more in-depth analysis.
- **Leverage:** A pool can leverage its collective buying power as a block to negotiate premiums and deductibles to the comparative advantage of its members.
- **Customization:** The scale of provision of member services, including risk control, claims management, and training, is sufficient to support customization.
- **Innovation:** A pool is better able to support the insurance industry's development of innovative products and offer unique forms of coverage, particularly with regard to efficient and cheap technology for indemnity and area yield index products.

Disadvantages

- **Lower diversification:** Disaster and/or agriculture insurance pools face high covariate risk from lower diversification, which can be detrimental to their solvency.
- **Cost:** The management of an insurance pool involves direct costs (e.g., secretariat overhead, salary, system cost) and indirect costs (e.g., time of regulators and other government officials).
- **Speed of decision-making:** As a pool involves policy decisions that can simultaneously affect all members, decisions are based on deliberations among pool members. Individual underwriters, on the other hand, can make prompt business decisions.

- **Flexibility:** A pool is better able to respond to the needs of individual insurers through variable deductibles, self-insured retention levels, and special coverage.
- **Subsidy policy:** A pool can provide data that could be useful to guide policy on premium subsidies, which, in principle, should be restricted to the cost of underwriting systemic risks.
- **Credibility:** By involving many key public sector stakeholders (e.g., the regulator and other government departments), pool members can demonstrate higher credibility to supply insurance.
- **Pricing stability:** Pools can involve a layer of capital to cover the first layer of losses, reducing the use of reinsurance and resulting in greater price stability.
- **Reinsurance:** Economies of scale facilitate the purchase of reinsurance at a more competitive price.

Preconditions

- **Reinsurance:** An agriculture or disaster insurance pool will have high covariate risks. It is imperative to have appropriate reinsurance arrangements to maintain the solvency of the pool.
- **Regulatory framework:** Insurance pools involve many stakeholders and underwrite large, collective risks. To prevent conflict, it is necessary to establish rules and regulations that define the rights and duties of all stakeholders.
- **Subject experts:** Managing a pool's risks and information keeping requires subject specialists. Often, it requires engaging subject specialists with a strong grasp of the specific risks being pooled and of the pool's reinsurance arrangements.
- **Medium-and long-term strategy:** As insurance pools are often created to address a market need in the medium (3–5 years) and long term (5–10 years), a well-planned strategy is necessary to envisage future functioning. For example, a strategy may consider winding up a pool once certain performance targets are met.
- **Information systems:** Adequate information technology systems are needed to record data, settle distribution costs and claims, and demonstrate solvency.

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