

Towards Resilient Public Finance

Sub-National Assessment of Fiscal Risks
in Critical Infrastructure Sectors
in Odisha



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Foreword



Amit Prothi

Director General
Coalition for Disaster Resilient Infrastructure

Odisha, located on the eastern coast of India, is highly vulnerable to a range of natural hazards. The state regularly experiences tropical cyclones, storm surges, and floods from the Bay of Bengal, along with droughts and heatwaves that are becoming more severe due to climate change. The frequency and intensity of these climate-induced hazards have been increasing, putting enormous strain on critical infrastructure systems and public finances. Each major disaster not only damages vital infrastructure and disrupts essential services but also hampers socioeconomic progress and redirects limited resources from long-term development and growth priorities. The resulting fiscal pressures limit the state's ability to respond swiftly, recover sustainably, and invest in future resilience. Therefore, strengthening financial preparedness against these compounding risks is essential for safeguarding Odisha's development trajectory.

As part of the Coalition for Disaster Resilient Infrastructure's (CDRI) efforts to mainstream resilience in infrastructure systems, this model disaster risk finance study has been conducted to assess the fiscal risks associated with disasters in key infrastructure sectors in Odisha. The study is among the first of its kind at the state level in India to systematically connect disaster-related infrastructure impacts to fiscal outcomes. It offers practical recommendations to enhance disaster risk financing strategies, strengthen institutional capacities, and manage contingent liabilities more effectively in the infrastructure domain.

This assessment aims to set a benchmark for sub-national disaster risk financing by providing a methodology to assess the economic and fiscal implications of disasters, review existing financing instruments, and highlight the importance of forward-looking, risk-informed public investment and budgetary practices. We believe this report will be a valuable resource for policymakers, financial planners, and development partners working towards strengthening fiscal resilience in Odisha.

We are grateful to our consultant, the Asian Disaster Preparedness Center (ADPC), and the Government of Odisha for their leadership and constructive involvement throughout this process. As Odisha continues to pursue resilient and sustainable development, it is crucial that disaster risk finance becomes a core element of public financial decision-making. This report marks a significant step in that direction.

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Executive Summary

Climate-induced disasters, such as floods, cyclones, and other hazards, can have serious consequences for human lives, economies, and public finances. These disasters not only disrupt lives but also have a significant impact on economies, often leading to reduced economic output, job losses, and property damage that can take years to recover from. On average, disasters and extreme weather events increase the fiscal deficit by 0.8 percent of GDP in lower-middle-income and 0.9 percent of GDP in low-income countries. These events can significantly affect individuals and infrastructure, adding to fiscal risks. They can also have a notable impact on government revenues by negatively affecting economic activity, resulting in reduced tax and non-tax revenues, as well as disruptions to tax collection efforts.

The state of Odisha is prone to multiple disasters, which significantly impact people's lives, livelihoods, and the state government's finances. In the past, Odisha has faced recurring hazards. Almost 35 percent of all cyclonic and severe cyclonic storms that strike the eastern coast have affected Odisha, often resulting in storm surges that lead to flooding in large coastal districts.

This report aims to evaluate the financial vulnerabilities and potential economic impacts of disasters on essential infrastructure in Odisha. By focusing on historical data, econometric modelling, and fiscal risk analysis, the study provides a comprehensive understanding of the fiscal challenges posed by disasters.

The report highlights that the average share of the State Disaster Response Fund (SDRF) to the total damage from the major cyclones that occurred from 2013 to 2022 is a mere 6 percent. This implies that to address the post-disaster needs, Odisha relies heavily on outside sources like the Central National Disaster Risk Management Fund (NDRMF) and others.

Apart from losses to life and property, hazards also lead to crop failure, decline in surface and groundwater levels, increasing unemployment and under-employment, migration, and indebtedness. Since 2014, Odisha has faced eight tropical cyclones. The estimated economic loss due to hazards from 2014 to 2021 is approximately INR 24,400 crore, which represents around 3.82 percent of the state's GDP (as of 2021-22). These major disasters have hindered the state's ability to achieve its desired growth rate in terms of gross state domestic product (GSDP).

Economic modelling to estimate indirect losses / network effects of disasters was conducted using state-level data and assessed using a panel model regression of fiscal variables against disaster intensity variables. The fiscal variables at the state level included aggregated fiscal data, while disaster impact variables incorporated human fatalities, affected populations, and direct damage.





The analysis suggested that a severe disaster is likely to increase the state's total expenditure, which could lead to a deterioration of its internal and debt positions. If an event as severe as the 1999 Odisha Super Cyclone were to occur again, the estimated increase in expenditure would be INR 389,765 lakh, including INR 63,850 lakh for social services and INR 2,163 lakh for relief payments. Odisha's internal debt issuance would increase by INR 10,838 lakh. Additionally, if a disaster similar to Cyclone Fani, which occurred in 2019, were to take place again, the projected increase in total expenditure will be INR 282,452 lakh, comprising INR 46,271 lakh for social services and INR 1,568 Lakh for relief payments. Odisha's internal debt issuance would increase by INR 7,854 lakh. The biggest fiscal impact is felt immediately after the disaster and is reflected in the fiscal variables of the following financial year. While it is likely that individual businesses and households experience long-term economic impacts, these effects are not large enough to show up at the state level. It is suggested that the Odisha government work together with the state statistics department and disaster recovery agencies to collect local-level data that could be used to quantify these smaller impacts.

Modelled flood losses also fit well with historical flood impact data provided by the Central Water Commission. While data per sector was not available for this modelling, we did have data on the financial impact of the disaster on all public utilities, which was used to model the flood hazard. The 1-in-50-year loss was estimated at \$621 million¹, which is comparable to the flooding of 2008, which resulted in public utility damages of \$683 million (adjusted for inflation) and an estimated return period of 64 years for that basin.

The statistically simulated losses for both flood and cyclone modelling outlined in this report provide appropriate estimates for losses for several return periods for the Odisha infrastructure losses. These figures serve as a valuable assessment of future fiscal risk and contribute meaningfully to discussions and planning concerning risk management.

Odisha has achieved remarkable fiscal consolidation in the past two decades and adhered to fiscal discipline that was anchored in a medium-term strategic framework. It has adopted significant reforms in public financial management by introducing budget ceilings, fiscal frameworks and "strategic elements to its annual budget cycle"² that aligns with the state's development priorities. These reforms catapulted Odisha to the top in the Fiscal Health Index (FHI³) of Niti Aayog. However, Odisha's long coastline and exposure make it vulnerable to natural events. The state needs to make higher provisions to mobilize necessary funds in any post-recovery phase.

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

² <https://blog-pfm.imf.org/en/pfmblog/2020/03/modernizing-budget-practices-in-odisha-state> "Modernizing Budget Practices in Odisha State."

³ [https://www.pib.gov.in/PressReleaseDetail.aspx?PRID=2117890®=3&lang=2#:~:text=Odisha%20leads%20the%20fiscal%20health,and%20Debt%20Sustainability%20\(64.0\).](https://www.pib.gov.in/PressReleaseDetail.aspx?PRID=2117890®=3&lang=2#:~:text=Odisha%20leads%20the%20fiscal%20health,and%20Debt%20Sustainability%20(64.0).) "Press Release: Press Information Bureau."

Lastly, Odisha has done an excellent job in social outreach and communication prior to any natural events like cyclones. The staggering mobilization of government personnel and transport to communicate and evacuate its citizens to safe shelters has been cited as a global best practice.

It's goal "zero-human casualties" and success during Cyclone Fani has been often cited as a shining example in disaster management globally. Furthermore In 1999, Odisha also became the first state in the country to set up a disaster management authority, the Odisha State Disaster Management Authority (OSDMA) much before the the establishment of National Disaster Management Authority (NDMA) in 2005.

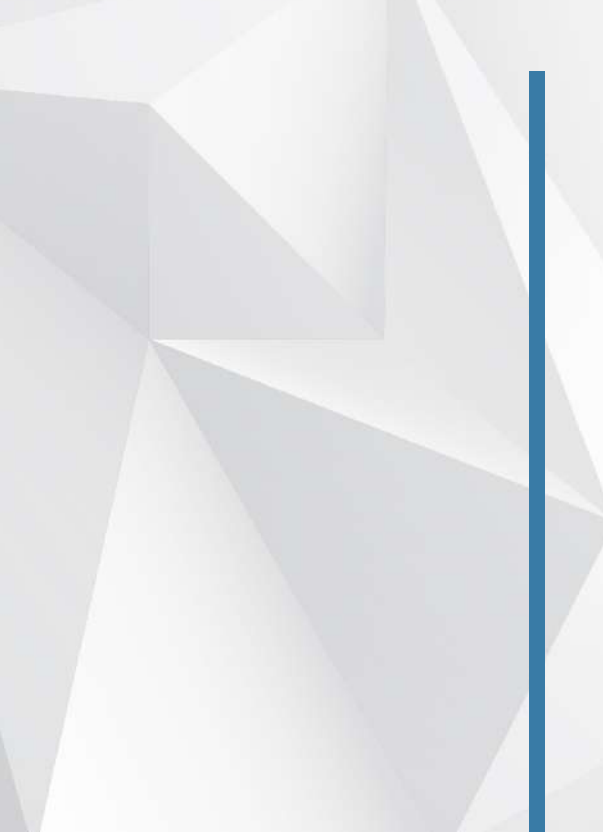






Chapter 1

Introduction



Introduction

Odisha is prone to recurring disasters that put substantial economic and fiscal pressures on the state. The damage to both physical and human assets, along with disruptions to businesses and a shrinking tax base, creates considerable financial strain. This situation necessitates substantial government spending on post-disaster response, recovery, and reconstruction efforts. The problem is further exacerbated by the interconnected nature of critical infrastructure, especially in the power and transport sectors. Disruptions in these areas can trigger cascading effects across the economy, destabilizing supply chains and various economic activities. In recent decades, disaster-related economic losses have increased, highlighting the urgent need for a comprehensive disaster risk management strategy that includes disaster risk financing (DRF) to improve the state's fiscal resilience.



The 'State-Level Assessment of Fiscal Risk Due to Disasters in Critical Infrastructure Sectors' project is a part of the Coalition for Disaster Resilient Infrastructure's (CDRI) initiative. The Coalition is committed to supporting its Member Countries in developing coherent DRF strategies through its 'Finance for Resilient Infrastructure Programme' (FRIP). These strategies would aim to address the financial necessities of rebuilding resilient infrastructure during both pre-disaster mitigation and post-disaster recovery and reconstruction phases.

This report assesses the fiscal risks associated with disasters in Odisha's critical infrastructure sectors, with a special focus on power and transport. The aim is to support evidence-based policymaking and improve financial preparedness for future events in Odisha.

The report is also aligned with and contributes to Odisha's Fiscal Risk Statement, which aims to comprehensively assess and address the financial vulnerabilities faced by the state. It provides in-depth insights into various fiscal risk mitigation strategies that can be employed. These strategies

are designed to enhance the state's capacity to withstand financial shocks associated with disasters, thereby promoting greater resilience and preparedness for future emergencies. Ultimately, this detailed analysis intends to equip policymakers with the necessary tools to safeguard Odisha's fiscal health and ensure resilient development in the face of natural threats.

Fiscal Risk Assessment Framework

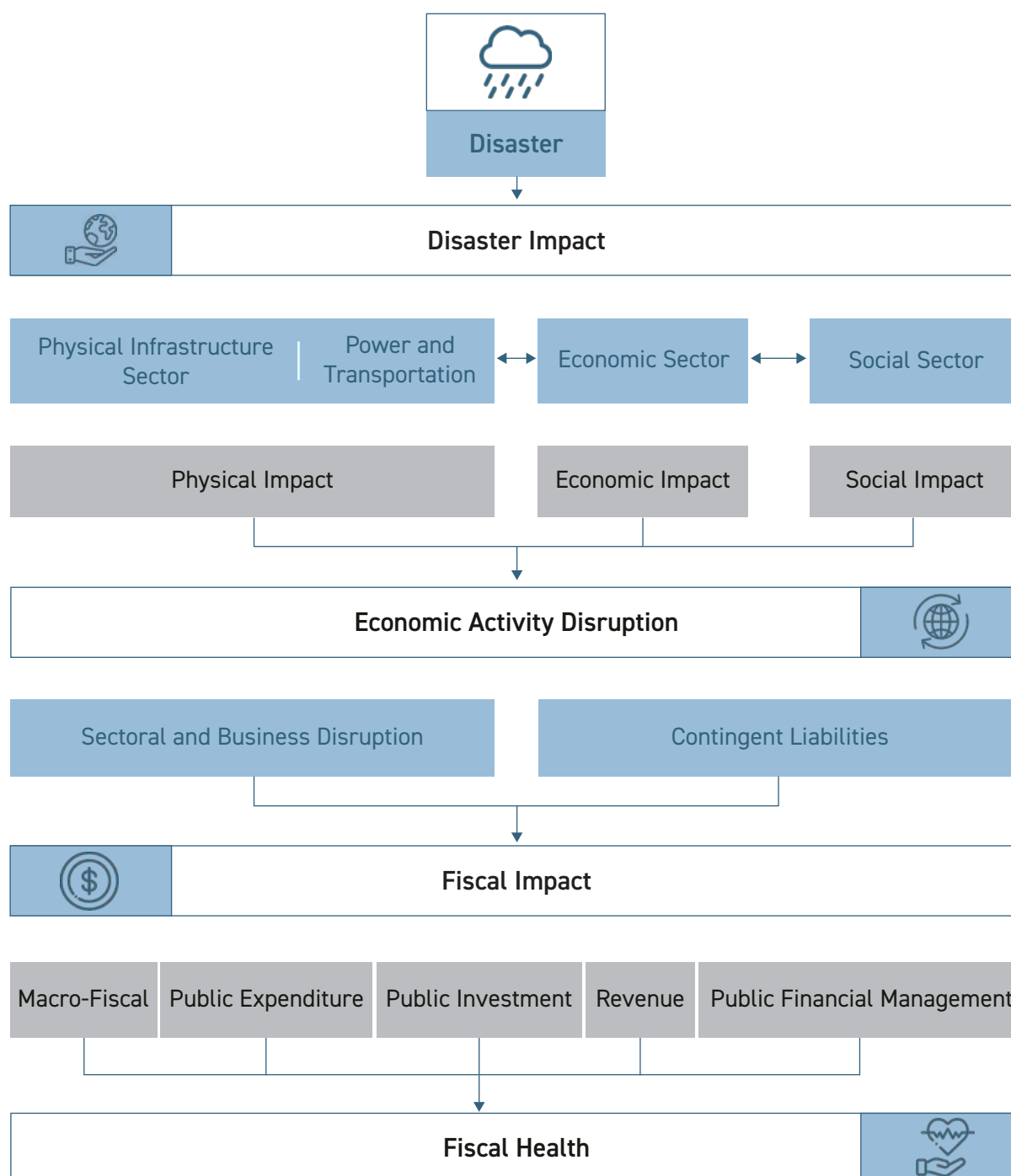
The International Monetary Fund (IMF) defines fiscal risk as the economic factors that may cause actual fiscal outcomes to diverge from projected or expected fiscal outcomes. The Organisation for Economic Co-operation and Development (OECD) describes fiscal risks as changes in the expected fiscal outcomes outlined in an economy's annual budget or forecasting documents. These fiscal risks can arise from macroeconomic shocks or contingent liabilities triggered by uncertain events (IMF, 2016). It is essential for governments to comprehend these risks and prepare for them by performing financial risk assessments. This proactive approach allows for the effective allocation of resources in the event of a disaster.

Fiscal risks can emerge from various sources, including macroeconomic shocks, financial sector crises, legal issues, subnational government liabilities, and challenges related to state-owned enterprises (SOEs). Hazards can lead to significant costs, averaging 1.5 percent of gross domestic product (GDP), and in extreme cases, these costs can rise to 6 percent. Therefore, they represent a significant source of fiscal risk. Additionally, public-private partnerships (PPPs) and private non-financial company liabilities can also result in government bailouts. According to a study by Bova et al. (2016), hazards generated the second-highest fiscal costs, accounting for 1.6 percent of GDP on average, following financial sector shocks, which accounted for 9.7 percent. To maintain sound fiscal management and ensure that the government can respond effectively during a crisis, it is essential to recognize and mitigate these risks.

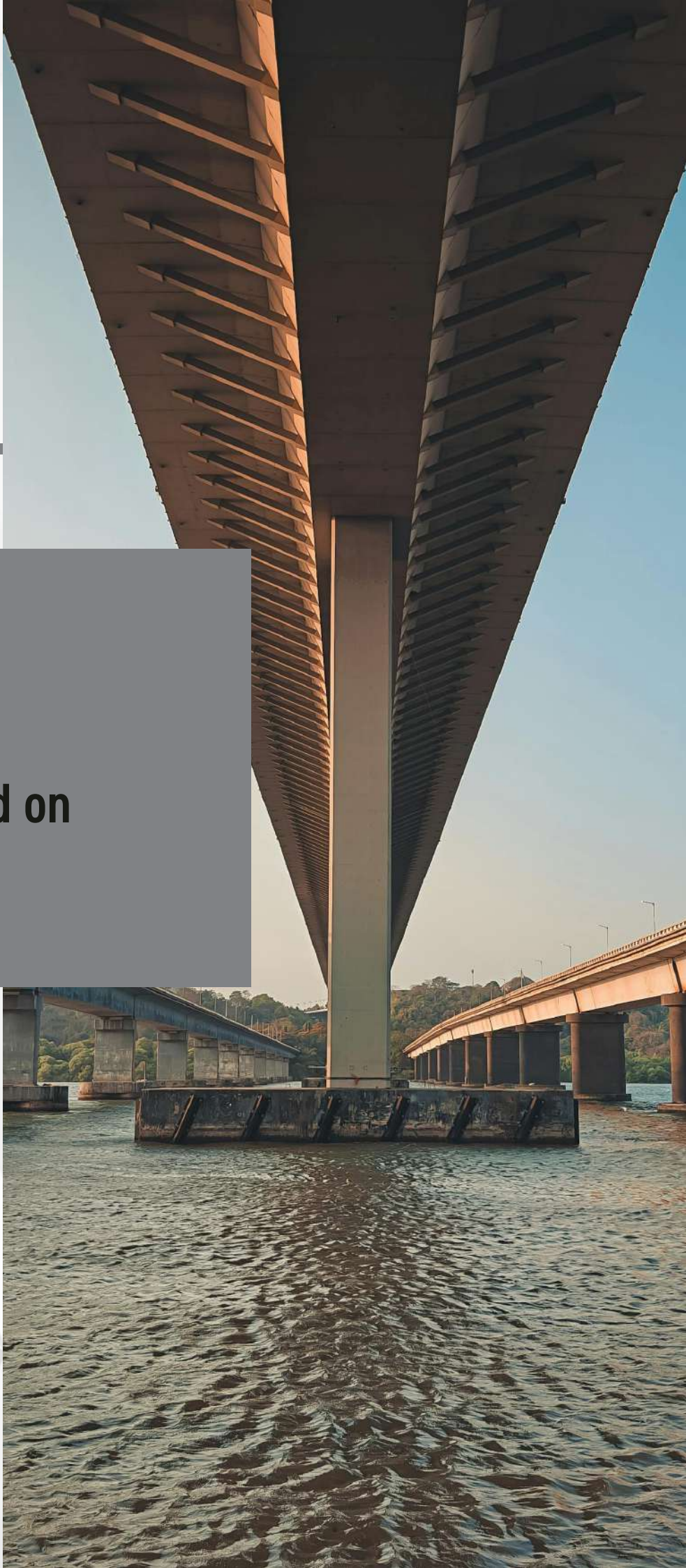
Disasters have profound fiscal implications for governments. According to the Inter-American Development Bank (IDB), the fiscal impact channels can be categorized into five channels: macro-fiscal, revenue-related, public expenditure, public investment, and public financial management impact (IDB, 2016). Understanding these channels is essential for policymakers to effectively manage the fiscal consequences of disasters.

Figure 1.1 presents a structured framework adopted for this report. The framework illustrates the cascading effects of disasters on economic and fiscal stability. It begins with the impact of disasters, which affects physical infrastructure, economic sectors, and social sectors. These disruptions lead to disruptions in economic activity, including sectoral and business disruptions, and create contingent liabilities for the government. As economic activities suffer, fiscal consequences emerge, categorized under the fiscal impact. This impact affects macro-fiscal stability, public expenditure, public investment, revenue, and public financial management. Ultimately, these cumulative fiscal pressures determine the overall fiscal health of the government.

Figure 1.1: Framework For Assessing Fiscal Risk Arising From Disasters



Source: Asian Disaster Preparedness Center – Author's illustration



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 severe effects on human lives, economies, and public finances. These disasters can result in loss of life, displacement of individuals, and damage to infrastructure. Consequently, they result in reduced economic output and increased demand for emergency services, reconstruction efforts, and social welfare programmes. In lower-middle-income countries, climate-induced extreme weather events contribute to an average increase in the fiscal deficit of 0.8 percent of GDP, while in low-income countries, the increase is approximately 0.9 percent of GDP. From a fiscal standpoint, the growing frequency and intensity of climate-related disasters elevate the risk of negative fiscal shocks. These events strain public fiscal accounts, leading to budget deficits and debt accumulation, resulting in weakened fiscal stability due to adverse effects on revenue and expenditure, increased public debt, delayed investment projects, and a cyclical fiscal policy.



Disasters can significantly impact government revenues, particularly by disrupting economic activity. This often leads to a decline in both tax and non-tax revenues due to decreased tax income, interruptions in international trade, and reduced labour hours. However, there may also be a post-disaster recovery boost that stimulates economic activity, resulting in short-term rises in foreign aid or tax revenue. In addition to immediate changes in revenue and spending, disasters also influence the government's assets and liabilities. For example, damage to public infrastructure increases the cost of repair or replacement. Unfortunately, many governments do not maintain complete balance sheets that account for non-financial assets, complicating assessments of the fiscal impact.

Between 1994 and 2013, hazards resulted in an estimated \$2.6 trillion global economic losses, equivalent to 4 percent of the world's GDP in 2015 (Guha-Sapir, Below, and Hoopis 2016). On average, across a sample of events between 1990 and 2014, the financial cost of hazards to a country was about 1.6 percent of its GDP. In some cases, the cost was much higher, with the most severe disasters

resulting in costs of up to 6 percent of GDP (Bova et al., 2016). A study by the IMF found that the maximum fiscal cost identified was 6 percent of GDP. Research shows that disasters and economic growth are negatively correlated; most studies indicate that disasters lower GDP both the short and long term. To ensure that governments are adequately prepared and do not underestimate the financial impact of these events, it is essential to improve predictions of future damage and enhance the study of low-frequency, high-impact disasters.

Figure 2.1: Fiscal Impact Channels of Disasters



Source: ADPC

As governments borrow money to fund recovery efforts, this may lead to budget deficits and increased public debt. Disasters can cause production losses, disrupt global trade, and lower tax collections due to lost labour hours and reduced business earnings, all of which significantly impact government revenue. Therefore, it is essential for governments to allocate funds quickly for emergency response and recovery. They often share disaster costs with local governments, which creates a need for further assistance. Public financial management faces difficulties in guaranteeing the effective use of disaster funds while maintaining transparency. Furthermore, public investment is affected, as money is diverted from future projects to rebuild damaged infrastructure.

Overview of Impact of Disasters in Odisha

Odisha, due to its unique geo-climatic conditions, is highly susceptible to various hazards. The state has a history of experiencing recurring hazards. Nearly 35 percent of all cyclonic and severe cyclonic storms that have impacted the eastern coast have affected Odisha. These storms are often accompanied by storm surges, which have led to the inundation of large coastal districts. Furthermore, the Mahanadi River and its tributaries pose a significant risk of severe flooding, and the state's 10 other major river systems also contribute to frequent flood occurrences. Additionally, Odisha faces risks from flash floods and landslides. A part of the state is susceptible to moderate earthquakes. Moreover, Odisha also faces severe heatwaves, lightning strikes, epidemics, forest fires, and road accidents (OSDMP, 2023).

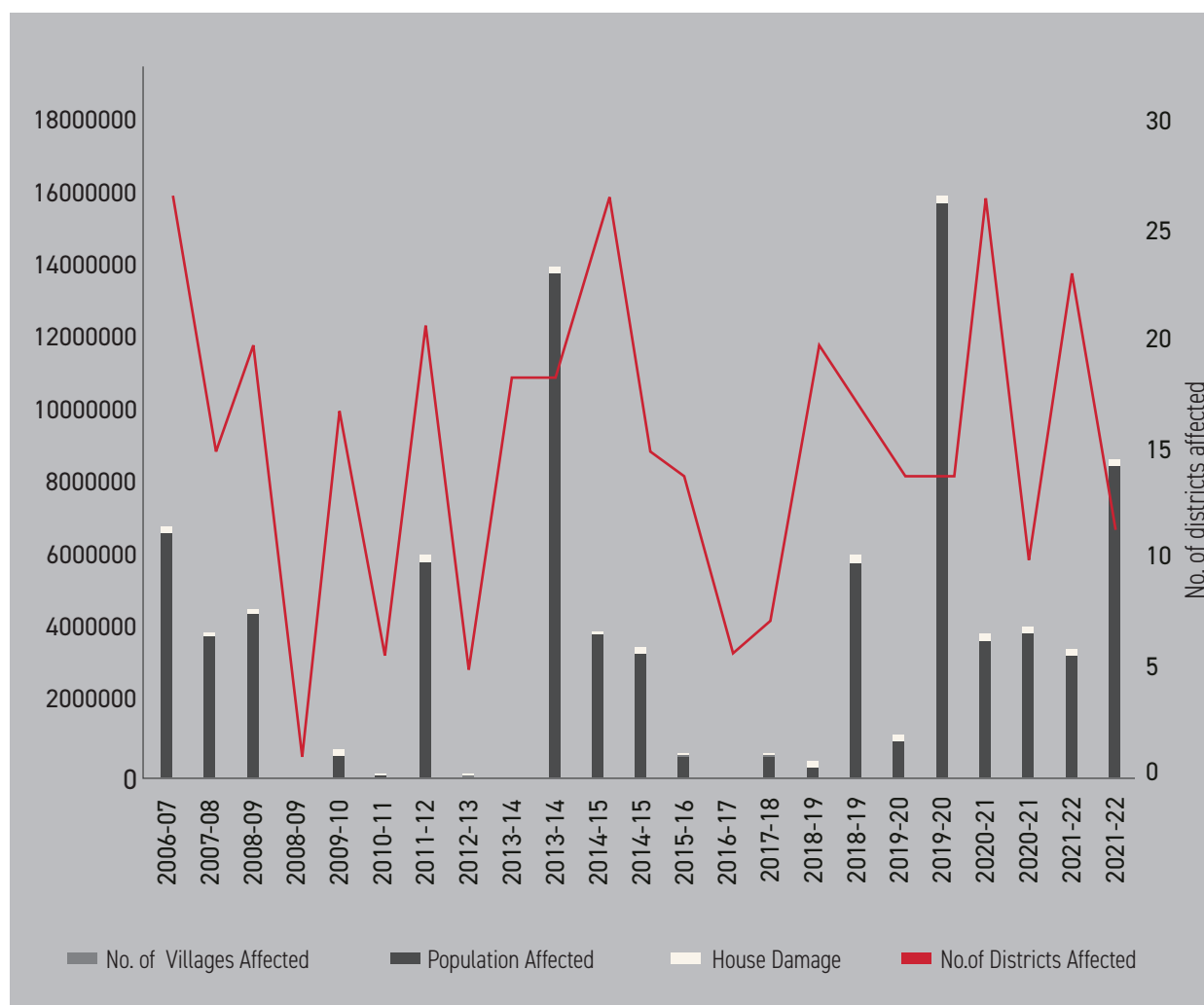
Odisha faces frequent floods and cyclones that affect multiple districts almost every year. Between 2006-07 and 2021-22, the state recorded 13 major floods and eight cyclones, along with a tornado in 2008-09 that impacted 12 villages, resulting in 16 deaths and damaging 1,425 houses. Many disasters have affected nearly all districts within the state. The major floods of 2006-07 and 2014-15 affected 27 districts. The most extensive cyclone damage occurred in 2019-20, which impacted 14 districts and affected over 15.99 million people. The highest number of affected villages was recorded in 2006-07 (18,912 villages), and in 2013-14 (18,374 villages due to floods and cyclones).



Recent improvements in disaster preparedness have reduced cyclone-related fatalities, but past events have resulted in significant loss of life. The flood in 2006-07 caused 105 deaths, while the flooding in 2008-09 led to 110 fatalities. The 2018-19 cyclone was among the deadliest, with 72 fatalities, followed by 64 deaths in 2019-20. Cyclones typically cause more damage to homes than floods. For instance, Cyclone Phailin in 2013-14 destroyed 651,590 houses and the 2018-19 cyclone damaged 396,769 homes. These recurring disasters, along with their effects on businesses and infrastructure, pose significant fiscal challenges for Odisha. The government has had to allocate substantial resources for relief efforts, rehabilitation, and rebuilding infrastructure after each disaster.

Figure 2.2 illustrates the frequent and widespread occurrences of disasters in Odisha. The consistently high number of affected villages and populations underlines the state's vulnerability to extreme weather events. This directly relates to the report's focus on the fiscal risk associated with damage to critical infrastructure.

Figure 2.2: Impact of Disasters in Odisha



Source: Compiled by ADPC from the Government of Odisha reports

Floods and cyclones are the most frequent and devastating disasters in Odisha. Located on the eastern coast along the Bay of Bengal, the state is particularly vulnerable to cyclones due to its geographical position in a region prone to tropical cyclones. Odisha regularly experiences cyclones, particularly during the pre-monsoon (April-June) and post-monsoon (October-December) periods. Several coastal districts in Odisha, including Puri, Khurda, Kendrapara, Jagatsinghpur, Balasore, and Bhadrak, are at higher risks of cyclone impacts. These districts face severe challenges, including strong winds, heavy rainfall, storm surges, and flooding. Flooding is primarily caused by major rivers like the Mahanadi, Brahmani, and Baitarani. Additionally, the lower reaches of the Subarnarekha, Rusikulya, Vansadhara, and Budha Balanga rivers also experience significant drainage congestion and flooding. According to the Odisha Flood Atlas 2019, eight districts, namely Bhadrak, Kendrapara, Jagatsinghpur, Balasore, Puri, Jajpur, Khordha, and Cuttack, are identified as the worst affected by floods based on the flood hazard index (Odisha Flood Atlas 2019).

The state has a moderate risk of earthquakes, with the highest probable intensity zone classified as VII. Earthquake magnitudes on the Richter scale in and around the state do not exceed 5.5. The districts with significant areas in this zone include Jagatsinghpur (100%), Puri (99.1%), Kendrapara (89.2%), Dhenkanal (80.2%), Cuttack (73.6%), Jajpur (43.1%), and Jharsuguda (42.2%). Odisha is also susceptible to tsunamis due to its extensive coastline along the Bay of Bengal. Six coastal districts, namely Balasore, Bhadrak, Kendrapara, Jagatsinghpur, Puri, and Ganjam, are at risk of tsunamis. A total of 316 villages in 22 blocks, along with 65 wards in six urban local bodies (ULBs), have been identified as prone to tsunamis, all located within 1.5 km of the coast.

The economic damage caused by past disasters offers valuable insights into trends and highlights the potential need for government financial assistance. The financial consequences of a disaster depend on how government spending and revenue are adjusted in response to the event. Additionally, governments may face future costs, known as disaster-related contingent liabilities, which arise from their obligations to respond to disasters. These liabilities can pose potential fiscal risks related to government finances. Once a disaster strikes, the funds earmarked for potential expenses may become actual expenditures. Especially in the case of a major disaster, the costs associated with these liabilities can exceed initial fiscal projections. This situation may lead to an increase in public debt and create additional fiscal risks to government finances, especially if the government has not made adequate provisions in advance to meet these possible costs (OECD, 2012; Mahul et al., 2014).

Damage refers to the replacement value of physical assets that have been completely or partly destroyed, rebuilt to the same standards that prevailed before the disaster. Losses represent the foregone economic benefits resulting from the temporary absence of the damaged assets and/or any other disruptions to economic activity caused by the disaster (ECLAC, 2003; UNDP, 2013).

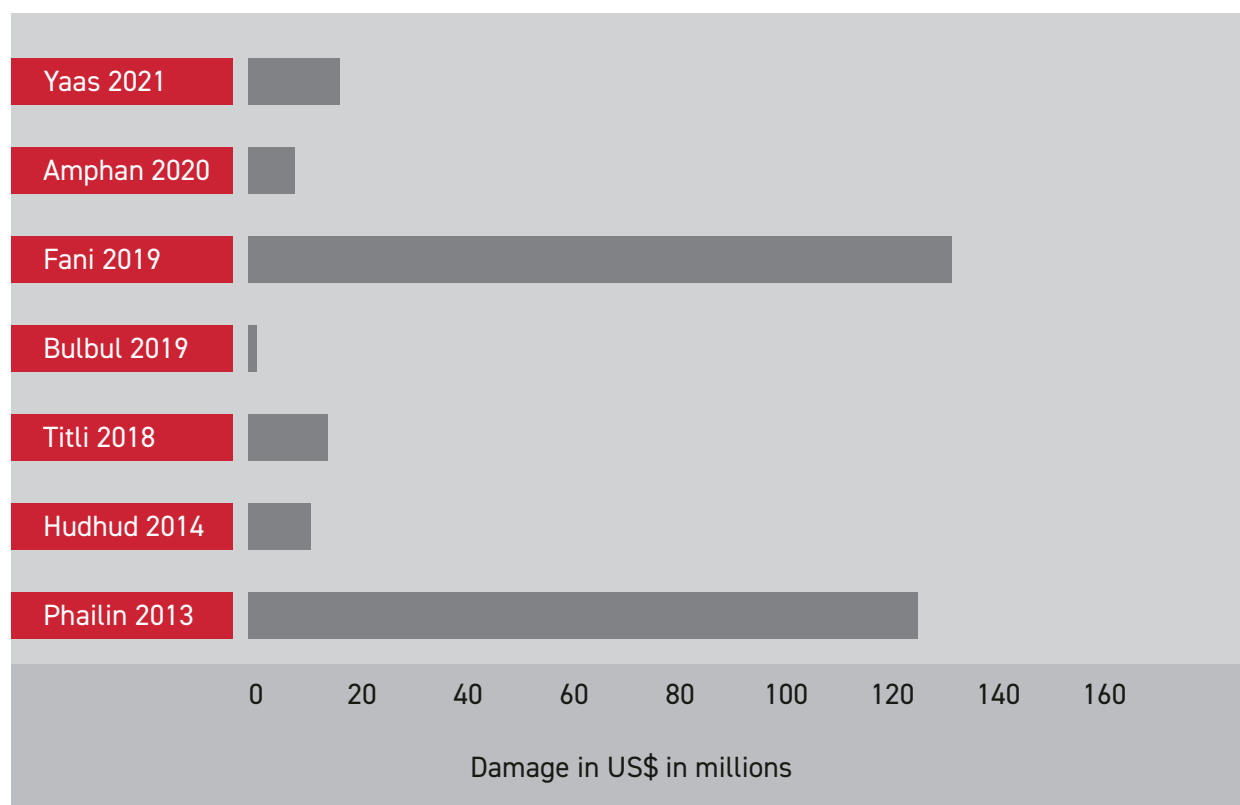
Impact of Disasters on Power Infrastructure

Cyclones generate strong winds, heavy rainfall, and storm surges, which severely impact critical infrastructure, particularly in the power sector. High wind speeds and flooding can damage transmission lines, substations, and distribution networks, resulting in prolonged power outages that disrupt economic activities and essential services. This recurring damage to power infrastructure escalates maintenance and reconstruction costs.

The power sector in Odisha has faced severe challenges due to multiple cyclones, resulting in widespread destruction of infrastructure. Cyclone Phailin (2013) caused damage estimated at \$111.73 million, affecting 211,014 electric poles, 93 extra high tension (EHT) towers, 4,074 km of EHT lines, and 38,997 substations. Cyclone Hudhud (2014) resulted in power infrastructure damage totalling \$43.76 million, impacting 1,754 distribution transformers, 1,089 km of low tension (LT) lines, and 2,156 km of 11 KV feeders. Cyclone Titli (2018) inflicted losses of \$103.27 million, damaging 2,598 distribution transformers, 10,415 LT poles, and 1,969 km of LT lines. Cyclone Fani (2019), one of the most devastating events for Odisha's power sector, resulted in damages totalling \$137.57 million, affecting 202,690 electric poles, 12,042 distribution transformers, and 107,132 km of conductors. In total, these major cyclones have caused damage exceeding \$381 million to the state's power infrastructure in recent years.

Figure 2.3 emphasizes the fiscal burden arising from recurring cyclone-induced damage. The high variability year-over-year supports the need for robust disaster risk financing strategies in Odisha's power sector.

Figure 2.3: Damage to Power Infrastructure



Source: Compiled by ADPC from the Government of Odisha reports

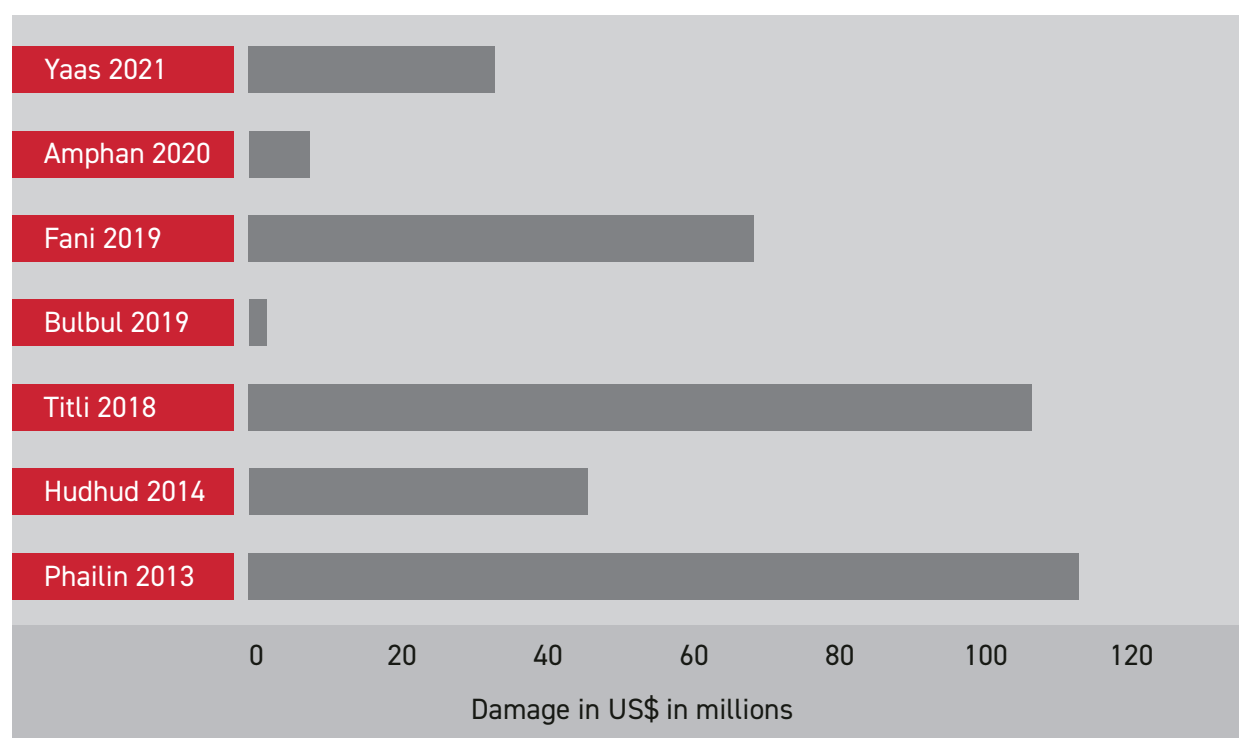
Impact of Disasters on Roads and Bridges

In Odisha, the construction and maintenance of roads and bridges are managed by various government departments, including the Public Works Department (PWD), Rural Development Department (RDD), Housing and Urban Development Department (HUD), and the Panchayati Raj and Drinking Water Department (PRDWD). Additionally, the National Highways (NH) in the state are overseen by Central Government departments.

The road network in Odisha, which includes state highways, district roads, village roads, and bridges, has suffered significant destruction due to cyclones and floods. Cyclone Phailin in 2013 caused an estimated \$111.73 million in damages, affecting 1,947 km of state roads, 8,099 km of district roads, and 17,637 km of village roads, along with 253 damaged bridges and culverts. Similarly, Cyclone Hudhud in 2014 resulted in road damage totalling \$43.76 million, impacting 917.5 km of PWD roads, 1,375 km of rural roads, and 1,922 km of Gram Panchayat roads. In 2018, Cyclone Titli caused \$103.27 million in road damage, affecting 2,486 km of PWD roads, 2,743 km of rural development roads, and 600 rural development bridges and culverts. Cyclone Fani in 2019 inflicted \$75.52 million in damage to road infrastructure, impacting 5,393 km of PWD roads, 6,251 km of rural development roads, and 750 km of urban roads. Lastly, Cyclone Yaas in 2021 caused damage amounting to \$36.77 million to roads and bridges, affecting 625.63 km of rural development roads and 166.86 km of PRDWD roads.

Figure 2.4 shows the impact of cyclones on roads and bridges infrastructure in Odisha from 2013 to 2021. It highlights the vulnerability of infrastructure, particularly in rural and urban roads. These damages highlight the interconnected fiscal stress and reinforce the case for investing in resilient transport systems.

Figure 2.4: Damage to Roads and Bridges



Source: Compiled by ADPC from the Government of Odisha reports

Fiscal Impact

The government of Odisha plays a major role in funding disaster relief and recovery efforts. Frequent and severe disasters in the state place a considerable strain on the fiscal health, leading to increased expenditures while disrupting revenue generation. The demand for emergency response, infrastructure restoration, and economic recovery creates a financial burden, often requiring the reallocation of funds from development-focused sectors. This results in widening the gap between disaster-related spending and revenue inflows, which ultimately affects Odisha's long-term economic stability. Despite receiving annual allocations from the State Disaster Response Fund (SDRF) and the National Disaster Response Fund (NDRF), the government often must divert funds from development schemes. The sources of revenue for the Odisha government are summarized in Figure 2.5.

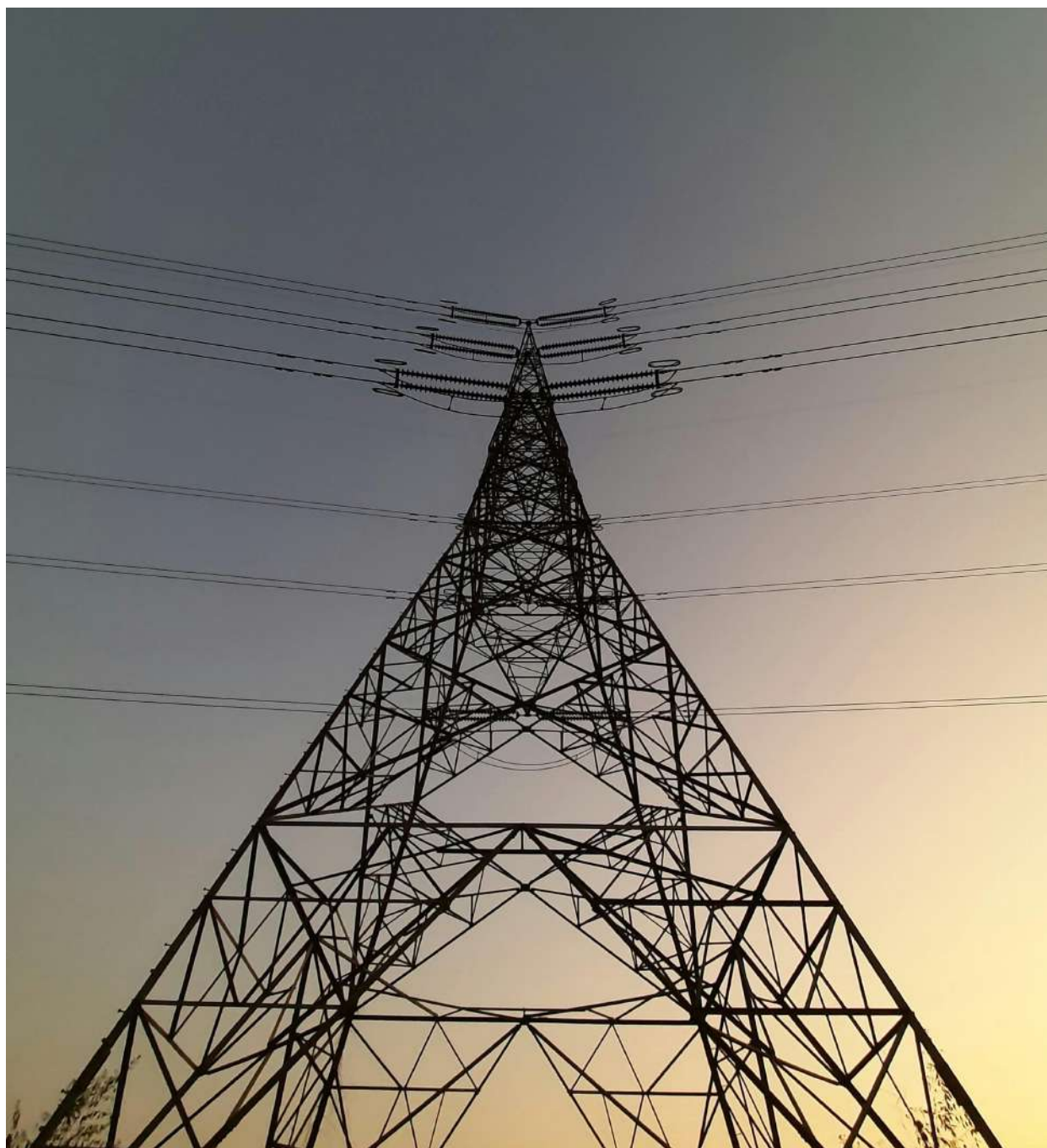
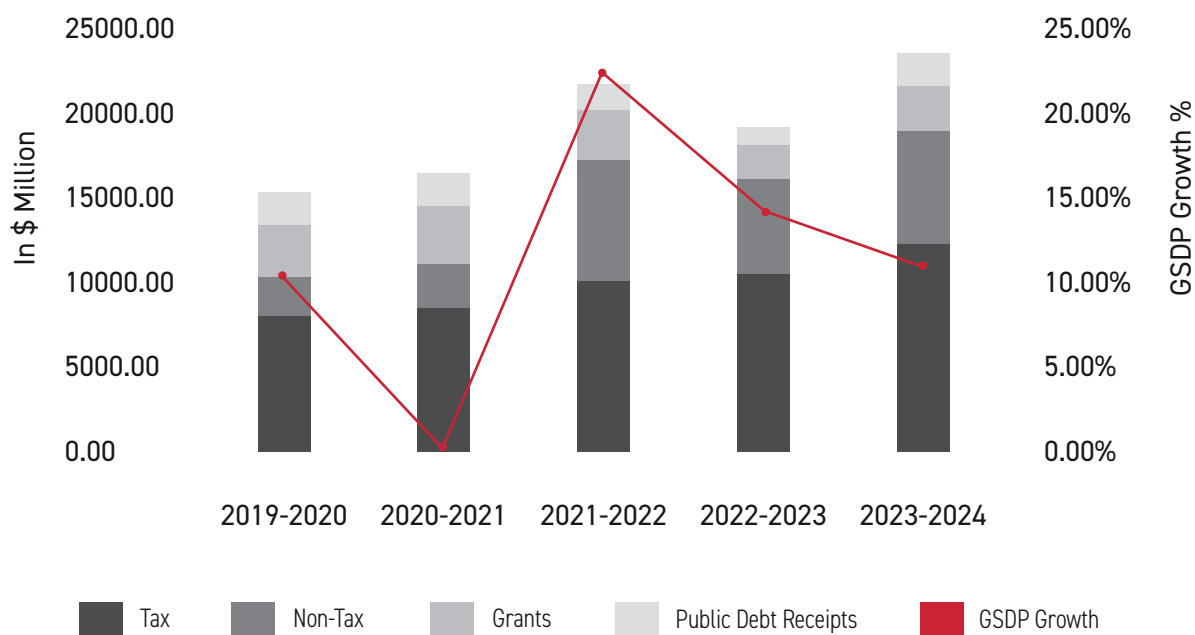


Figure 2.5: Government Sources of Revenue



Source: Compiled By ADPC from the Government of Odisha reports

Figure 2.5 indicates a shift towards increased public debt and decreased reliance on grants after disasters. This trend is closely linked to the fiscal strain and emphasizes the need for stable and diversified revenue mechanisms. The state primarily depends on the SDRF and the NDRF to finance immediate relief efforts. However, the costs associated with post-disaster reconstruction significantly exceed the available funds, which necessitates additional allocations from the state budget. Disasters weaken the state's revenue-generation capacity by disrupting industries, agriculture, and services, leading to lower tax collections. Key revenue losses include the following:

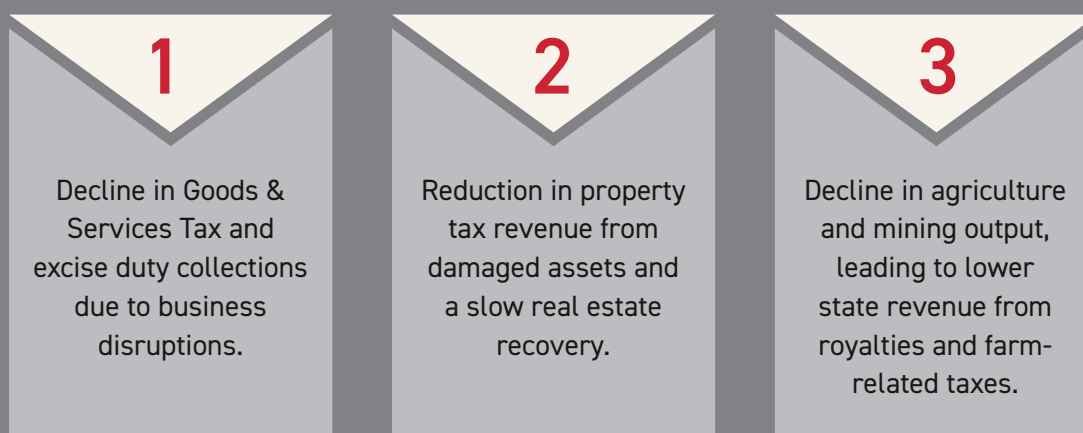


Table 2.1: Summary of Revenue 2019-2024 (In \$ Millions)

Description	2019-2020	2020-2021	2021-2022	2022-2023	2023-2024	Change	Change(%)
Tax Revenue	8,326.36	8,407.76	10,406.94	10,903.23	12,662.36	4,336.00	52.10%
Goods and Services Tax	2,897.76	2,884.58	3,670.63	3,740.23	4,727.74	1,829.98	63.20%
Taxes on Income & Expenditure	2,485.35	2,326.11	2,846.70	3,498.31	4,002.21	1,516.87	61.00%
Taxes on Property, Capital & Other Transactions	286.00	482.28	407.09	332.78	389.69	103.70	36.30%
Taxes on Commodities & Services other than Goods and Services Tax	2,657.26	2,714.79	3,482.52	3,319.76	3,542.72	885.45	33.30%
Non-Tax Revenue	1,942.94	2,655.34	7,157.25	5,195.89	6,358.22	4415.29	227.20%
Grants-in-Aid & Contributions	3,203.78	3,138.30	2,626.40	2,213.66	2,520.09	683.69	21.30%
Public Debt	9,078.36	10,816.04	9,561.77	7,772.73	8,730.91	347.45	3.80%

Source: Compiled by ADPC from the Government of Odisha reports

The combined effect of rising expenditure and declining revenues creates a fiscal gap that threatens Odisha's economic resilience. Key trends include the following:



Increase in debt burden

The debt-to-GSDP (gross state domestic product) ratio rises after disasters as the state borrows more funds to finance recovery efforts.



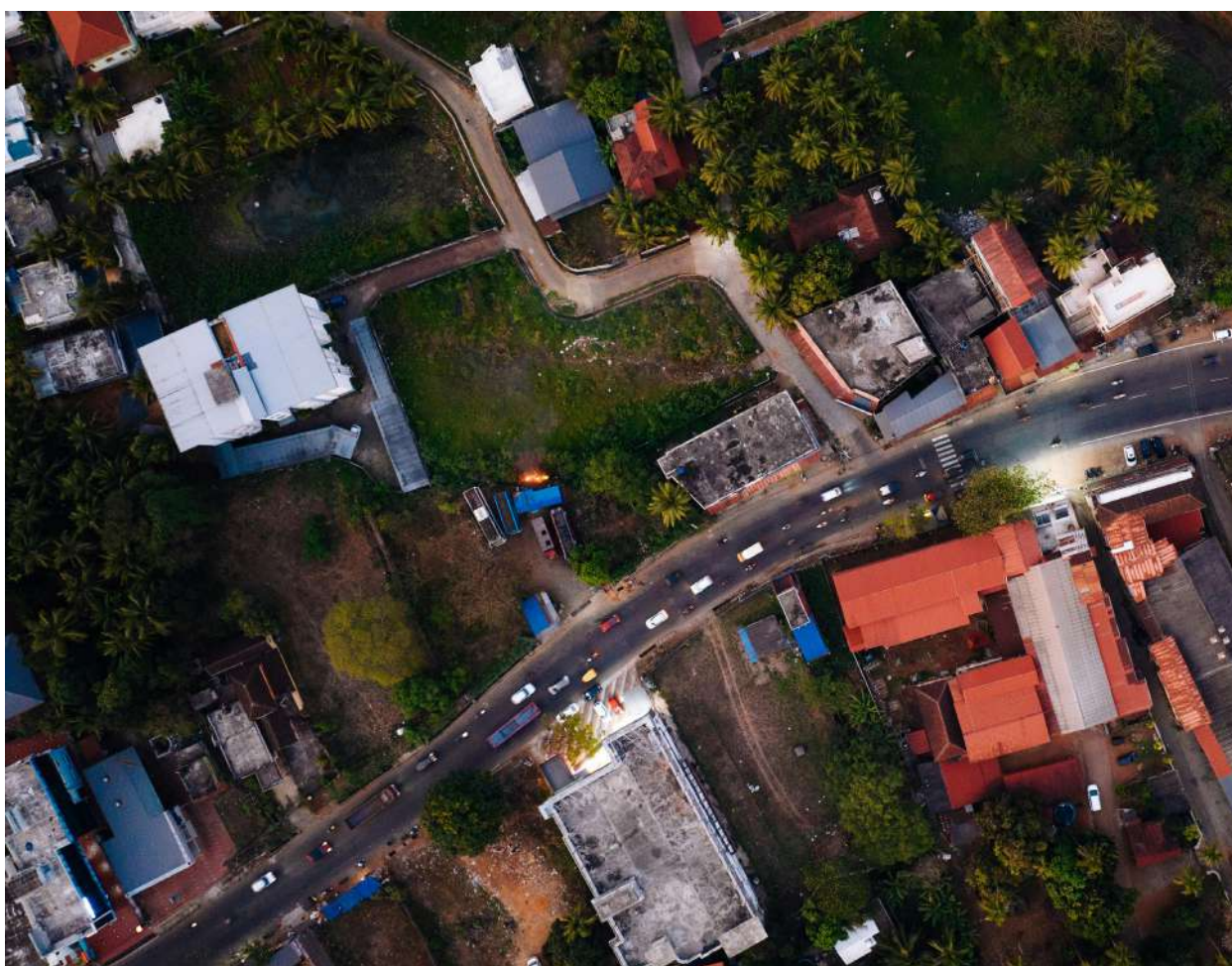
Diversion of developmental funds

Essential infrastructure projects face delays due to funds being redirected for post-disaster repairs.



Dependence on Central assistance

Odisha is increasingly reliant on NDRF grants, which are often insufficient to cover the total cost of recovery.





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 examines the different DRF plans and policies implemented by national and state governments that provide funding mechanisms for post-disaster response and recovery measures. The goal is to understand the current DRF landscape, focusing on the specific mechanisms and processes in place, the hazards and assets or activities covered by the current national framework, and the amount of funding available. Additionally, this section provides detailed information on the existing budgetary provisions and sources of government funding. It also includes a historical account of disaster-related expenditures from different government and non-government sources.

Institutional Framework for Disaster Risk Management

India has a well-established framework for disaster risk management (DRM) that operates at the national, state, and district levels. At the national level, the Disaster Management Act 2005 serves as the legal foundation for disaster preparedness, mitigation, and response. The National Disaster Management Authority (NDMA), led by the Prime Minister, is responsible for formulating policies and guidelines related to disaster management. The Ministry of Home Affairs (MHA) oversees disaster response efforts, while various sector-specific ministries address specific hazards, such as cyclones, floods, and earthquakes.



In Odisha, the Odisha State Disaster Management Authority (OSDMA), the Revenue and Disaster Management Department, and the Office of the Special Relief Commissioner (SRC) are the main organizations responsible for managing all aspects of disaster management, including mitigation, response, and recovery. OSDMA is tasked with promoting an integrated and coordinated disaster management system. This involves the prevention and mitigation of disasters through collaboration among the state, local authorities, stakeholders, and communities. The SRC Office plays a crucial role in facilitating relief, restoration, and rehabilitation during a disaster, ensuring that effective emergency response and relief efforts are coordinated. The district administration works closely with line departments and Panchayat Raj Institutions (PRI) at the district level. Its responsibilities include overseeing pre- and post-disaster management activities in the district and assisting with community training, awareness programmes, and the installation of emergency facilities. To implement these activities effectively, the district administration receives support from PRIs, non-governmental organizations, and the private sector. All major stakeholders, such as state government line departments, the district administration, UN agencies, technical institutions, PRIs, ULBs, communities, and non-governmental organizations (NGOs), play a crucial role in disaster risk management.

Disaster Risk Financing Mechanisms in India

In India, the responsibility for disaster risk financing is shared between the states and the Union government. The states lead disaster response efforts, including rescue operations, evacuations, relief efforts, and providing aid to affected individuals. The Union government offers financial and technical assistance as needed. State governments cover most of the disaster-related costs. In the event of a major disaster, the Union government provides additional funding to supplement and replenish the state funds.

The Disaster Management Act, 2005 has brought about significant changes in how disasters are managed. This act provides financial assistance through the SDRF and NDRF for disasters that have been officially declared. These funds were established under Sections 46 and 48 (1) of the Disaster Management Act, 2005. The current disaster risk finance mechanism is governed by the recommendations of the 15th Finance Commission (FC-XV) for the period 2020-25. The FC-XV recommended two major funds: the State Disaster Risk Management Fund (SDRMF) and the National Disaster Risk Management Fund (NDRMF).

Historical Perspective of Disaster Risk Financing in India

DRF in India is based on the Finance Commission's (FC) recommendations. The FC-II (1957-62) introduced the 'margin money scheme' to allocate specific amounts to states for relief measures. FC-VI (1974-79) was the first to receive a formal term of reference concerning relief expenditure financing, a practice that subsequent commissions have also included. Despite this, until FC-VIII (1984-89), no changes were made to the system established by FC-II and the same approach persisted. FC-IX (1989-95) recognized the inadequacies of the margin money scheme for financing relief expenditures. Instead of relying on this outdated scheme, it recommended a new approach that involved providing substantial funds directly to the states. This new system would allow states to manage emergency situations independently, without needing assistance from Central teams, state memoranda, or margin money. As a solution, the Commission suggested creating a calamity relief fund (CRF) for each state.

The FC-X (1995-2000) proposed implementing specific operational procedures for the CRF. Additionally, it recommended establishing a national fund for calamity relief (NFCR) to assist any state impacted by a rare and severe disaster. FC-XI (2000-05) continued to support the existing system of the CRF while also reviewing the functioning of the NFCR. It found that not only had the entire corpus of the fund been exhausted in three years, but it also failed to make sufficient funds available to address the needs of calamities of rare severity. As a result, the FC-XI recommended establishing a national calamity contingency fund (NCCF) with an initial corpus of INR 500 crores, which was intended to be replenished through the imposition of a special surcharge on Central taxes.

Disaster Risk Financing Mechanisms in Odisha



Post-disaster financing sources are crucial for states to recover and rebuild after a disaster strikes. When a disaster occurs, states often rely on a combination of financial sources to fund their recovery and reconstruction efforts. The primary sources of DRF in the state are the SDRMF and NDRMF. The SDRMF is divided into two main components: the State Disaster Response Fund (SDRF) and the State Disaster Mitigation Fund (SDMF). The SDRF is allocated 80 percent of the total SDRMF, while the SDMF receives the remaining 20 percent. Within the SDRF allocation of 80 percent, there are three sub-allocations: response and relief (40%), recovery and reconstruction (30%), and preparedness and capacity building (10%). Similarly, the NDRMF consists of two components: the NDRF and the National Disaster Mitigation Fund (NDMF). Additionally, the NDRF has sub-allocation into response and relief (40%), recovery and reconstruction (30%), and preparedness and capacity building (10%).



Emergency credit from international financial institutions such as The World Bank and the Asian Development Bank (ADB), provides loans and grants to enable countries to respond promptly, recover effectively, and rebuild more resilient communities. Beyond immediate relief, emergency credit also supports long-term recovery efforts, including reconstruction, restoring essential services, and rehabilitation of affected communities.



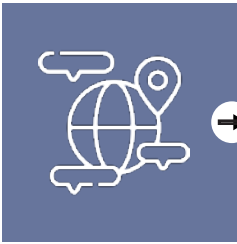
Private sector finance through both corporate social responsibility (CSR) and non-CSR funds by the private sector, has emerged as a significant player in disaster relief and recovery efforts. Beyond financial contributions, the private sector offers innovation, expertise, and efficiency that enhance disaster relief and recovery efforts.



Prime Minister's Relief Fund in India, a charitable trust, was established to provide immediate financial assistance to affected communities by natural catastrophes, accidents, and other calamities to cover medical expenses, rehabilitation, and education. The fund is managed by the Prime Minister's Office (PMO) and is exclusively utilized for rehabilitation efforts during crises.

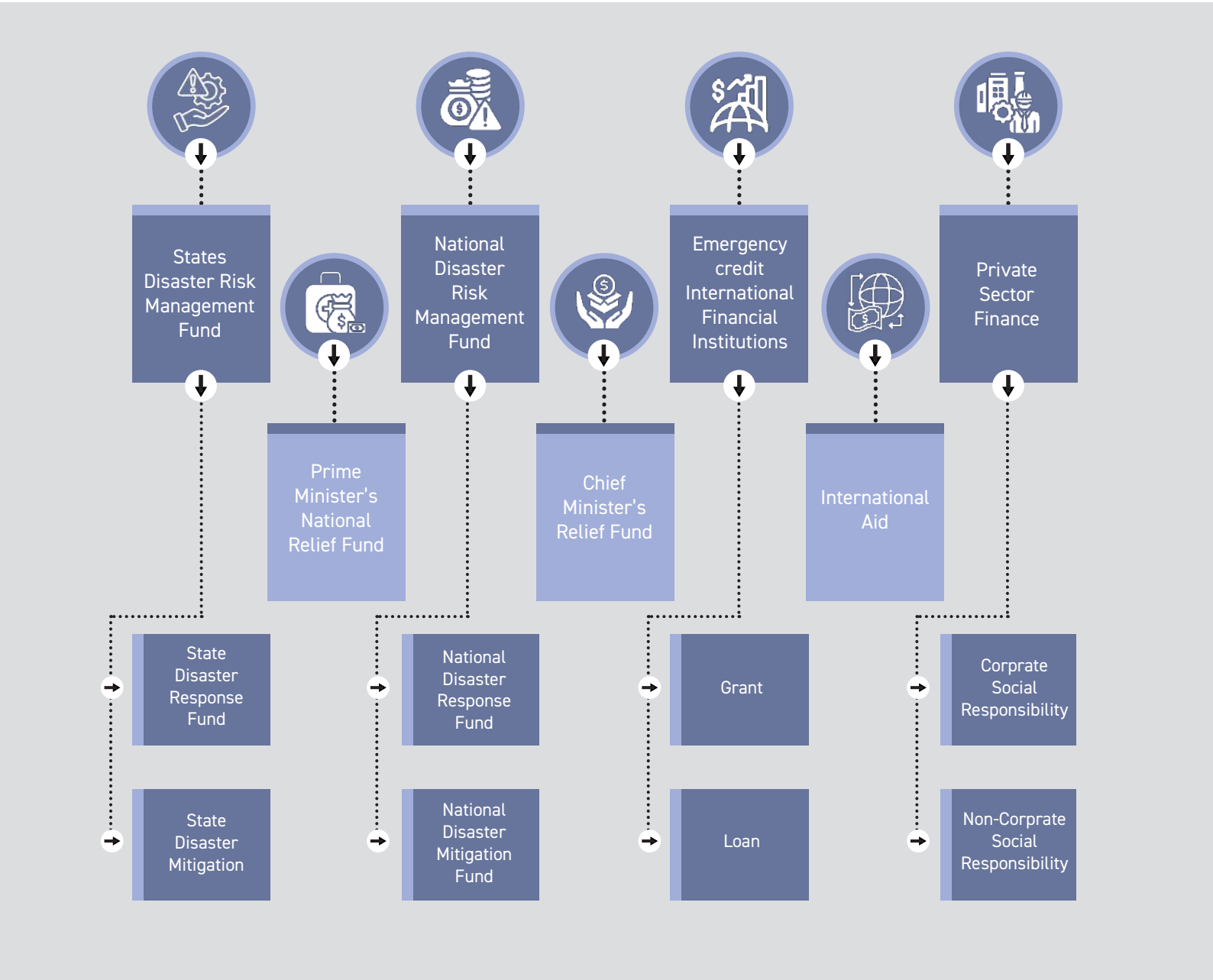


The Chief Minister's Relief Fund aims to provide immediate assistance to the people of Odisha in times of distress. This fund relies on budgetary allocations from the Government of Odisha, along with voluntary donations from the general public and various social responsibility organizations.



International assistance for disasters in Odisha, as in any other Indian state, typically involves cooperation and support from foreign governments, international organizations, and NGOs. Refer to Figure 3.1

Figure 3.1: Sources of Disaster Risk Financing



Source: ADPC

NDRF Allocation Mechanism

The NDRF provides financial support for severe calamities, supplementing the provisions of the SDRF. When a severe disaster occurs and the funds available in the state's SDRF are insufficient, the state government can request additional assistance from the NDRF by submitting a memorandum.

This memorandum is then reviewed to assess the estimated funding requirements based on the established items and expenditure norms for both the SDRF and the NDRF. After a preliminary examination, if it is determined that the SDRF has sufficient funds to provide relief according to regulations, the states are notified accordingly. However, if further assistance is necessary, Inter-Ministerial Central team is sent to the affected area for an on-site evaluation.

The Indian National Executive Committee (NEC) then reviews the Central team's report through a sub-committee. This sub-committee assesses the relief expenses that are eligible for funding from both the NDRF and SDRF. Finally, the high-level committee considers the sub-committee's recommendations and decides the amount of immediate aid to be allocated from the NDRF.

The Afat Vimo Microinsurance Scheme in Odisha

The All-India Disaster Mitigation Institute (AIDMI) has collaborated with the Society for Women Action Development (SWAD), the United India Insurance Company, the Life Insurance Corporation of India, and other partners to develop and market a disaster microinsurance product. It is called Afat Vimo and offers a combination of life and non-life coverage for a premium of only a few dollars a year. After Cyclone Phailin struck Puri, a survey was conducted among Afat Vimo customers and other residents in Odisha to assess the effectiveness of the microinsurance. The survey findings revealed that policyholders were able to use their payouts to repair their damaged homes, and the insurance coverage had strengthened their resilience to extreme weather events.

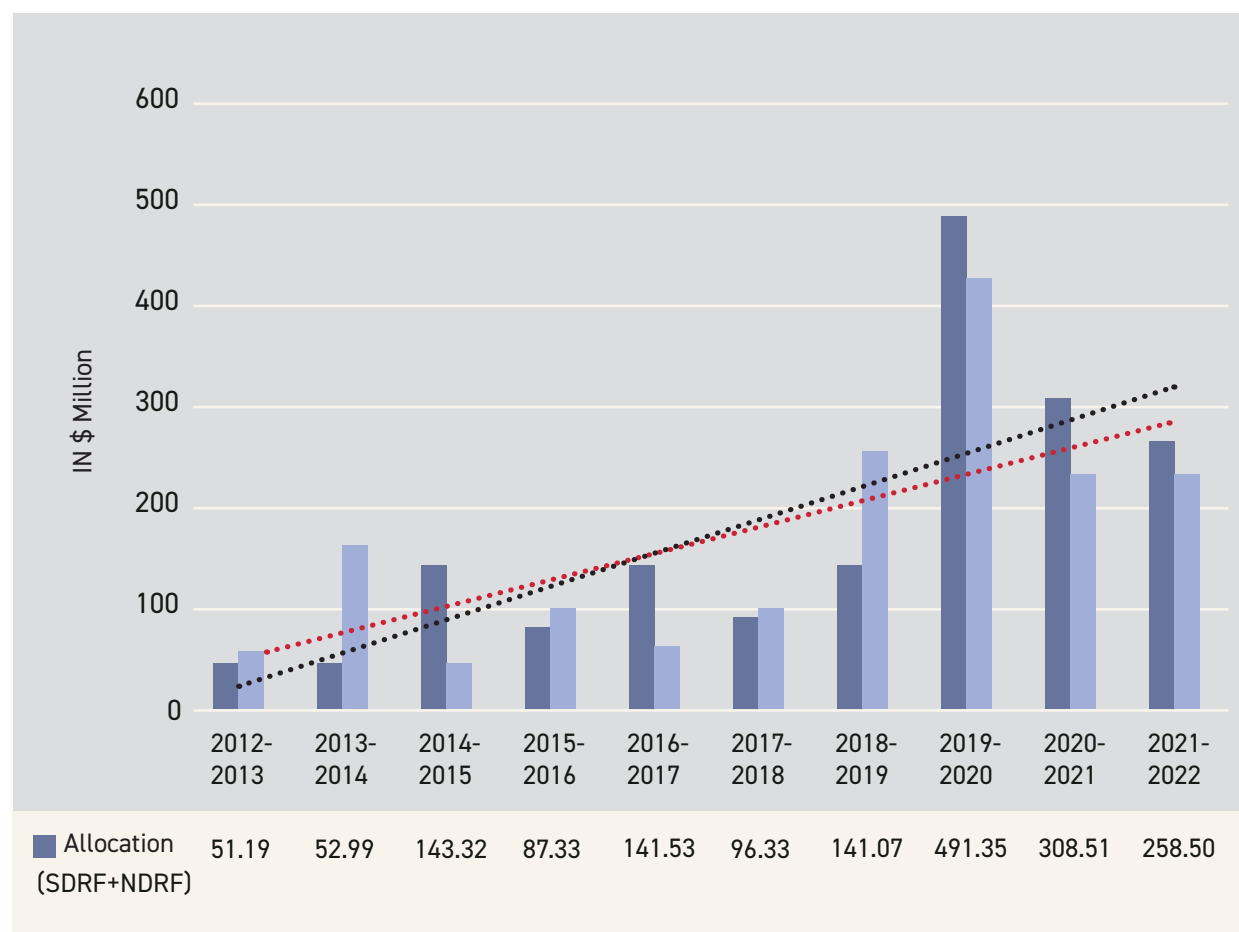
Trend Analysis of Disaster Risk Financing in Odisha

This section provides trend analysis on the allocation and expenditure of primary disaster financing sources, specifically the SDRF, NDRF, and Prime Minister's National Relief Fund (PMNRF) in Odisha. The SDRF is allocated 80 percent of the total SDRMF, while the SDMF receives the remaining 20 percent. The total allocation under the SDRF for a particular state consists of the sum of the Central

share (75%) and the state share (25%). However, it is essential to note that this allocation may vary yearly. Adjustments can be made in response to changes in disaster management guidelines, financial limitations, and other circumstances. Additional contributions from other sources, such as grants or donations from foreign governments or organizations, can also supplement the allocation. In addition to the SDRF, the NDRF provides funding for major calamities. In the event of a severe disaster, if the state's SDRF is insufficient, the state can request additional Central assistance from the NDRF by submitting a memorandum. Since the fiscal year 2018-19, expenditures from both the SDRF and the NDRF have significantly increased. This rise is primarily attributed to the Indian central government's designation of COVID-19 as a 'disaster' under the Disaster Management Act, 2005. Consequently, funds from the SDRF have been allocated for activities related to COVID-19 management and research initiatives. The expenditure has consistently surpassed the allocated amounts. This phenomenon can be attributed to the carryover of remaining balances from previous fiscal years, which are not factored into the annual allocations (Special Relief Commissioner, Government of Odisha 2022).

Figure 3.2 illustrates the comparative allocation and utilization of SDRF and NDRF funds in Odisha (2012-22). The expenditure often exceeds the allocation, reflecting not only the underestimation of disaster impacts but also highlighting funding gaps that can destabilize post-disaster recovery.

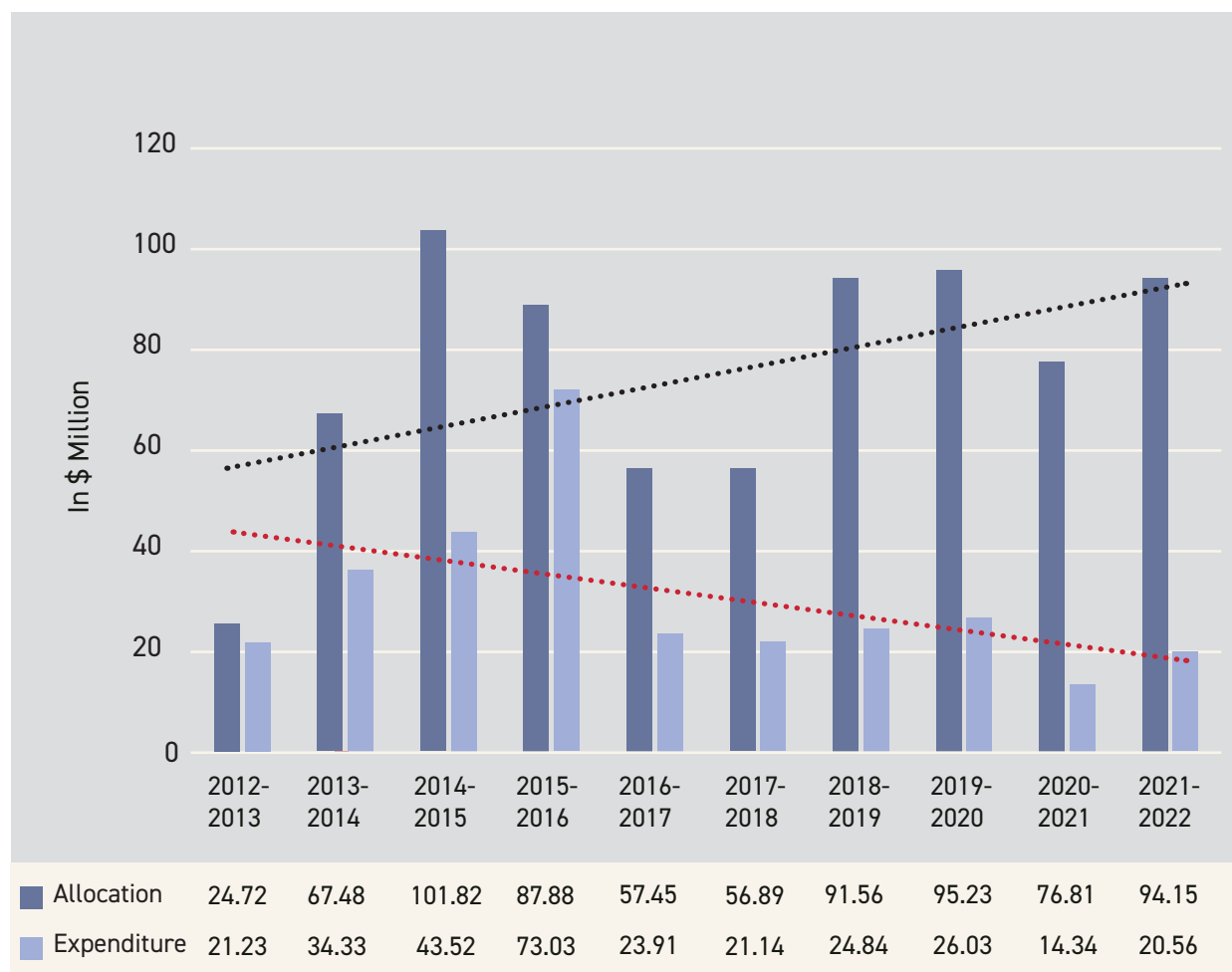
Figure 3.2: Annual Allocation and Expenditure from SDRF and NDRF in Odisha (2012-13 To 2021-22)



Source: Compiled by ADPC from the Government of Odisha reports

Figure 3.3 illustrates the status of fund allocation and expenditure from the PMNRF from 2021-22. The fund aims to alleviate the suffering of individuals affected by disasters and help them regain stability in their lives. It is entirely funded by public contributions and does not receive any budgetary assistance from the government. The highest allocation to the fund occurred during the 2014-15 fiscal year, while the most significant expenditure took place in the 2015-16 fiscal year, following the impacts of Cyclone Phailin and Cyclone Hudhud.

Figure 3.2: Annual Allocation and Expenditure from Prime Minister's National Relief Fund in Odisha (2012-13 To 2021-22)



Source: Compiled by ADPC from the Government of Odisha reports

Chapter 4

Economic Modelling



Economic Modelling

Estimating the indirect effects of hazards has traditionally been challenging, leading to less emphasis on this area in research. Direct effects — such as immediate asset damage, loss of life, and the costs associated with delivering aid — are highly visible, the indirect effects can be more systemic and less noticeable. This section provides a sector-specific estimation of the indirect impacts of disasters, focusing on how losses in one sector can affect related sectors. The assessment quantifies these indirect effects of disasters in terms of loss of income and value-added or overall economic output. Economic modelling techniques are designed to assess the economic activities reliant on specific infrastructure segments and to measure the costs associated with their loss. This analysis includes the interruption of economic activity due to the loss of essential infrastructure and the decreased productivity that results from dependence on less efficient alternatives.

Direct effects — such as immediate asset damage, loss of life, and the costs associated with delivering aid — are highly visible, the indirect effects can be more systemic and less noticeable. This section provides a sector-specific estimation of the indirect impacts of disasters, focusing on how losses in one sector can affect related sectors. The assessment quantifies these indirect effects of disasters in terms of loss of income and value-added or overall economic output. Economic modelling techniques are designed to assess the economic activities reliant on specific infrastructure segments and to measure the costs associated with their loss. This analysis includes the interruption of economic activity due to the loss of essential infrastructure and the decreased productivity that results from dependence on less efficient alternatives.

The indirect impact of disasters was modelled using a panel regression model, which compared government fiscal variables against a derived measure of disaster intensity (Noy 2016a). This analysis employed a fixed effects panel model that included both state and time variables. Such panel models are routinely used in the economic analysis of complex, real-world issues that cannot be adequately represented by cross-sectional or time-series data alone (Balaji 2013). A fixed effects model with both state and time variables incorporates cross-sectional data, representing each state's intrinsic characteristics that do not vary over time (state-invariant aspects), as well as time series data, which comprise variables that change over time but remain constant across states (time-invariant aspects). By including data from both before and after the disaster event across affected and unaffected states, this panel model can effectively quantify the fiscal implications of the event.

Equation 2: Panel model equation

$$Y_{it} = \alpha_i + \sum_{j=1}^p \Phi_j Y_{i,t-j} + X_{it}\beta + \varepsilon_{it}$$

Y	is the modelled fiscal variable
α	is the fixed effects for the states
p	are time lag variables
Φ	is the number of lags included in the model
X	is the disaster intensity variable
ε	is the error term

All modelling was done using the R statistical language, with the main package being plm. The plm package in R is a collection of functions specifically designed for analyzing panel data. It also provides methods for conducting hypothesis testing, including tests for individual and time effects (Croissant and Millo 2008).

Economic Panel Model and Data

States included in the Economic Panel Model

In this study, each Indian state is treated as a cross-sectional unit within the econometric panel model. By including data from both before and after the disaster event, as well as from affected and unaffected states, the panel model can quantify the fiscal implications of a disaster on each state's government finances. However, historical data is not available for all Indian states, as some were established more recently through the division of existing states. Moreover, the creation of new states often results in significant changes in the fiscal variables of the states from which they were formed. To address these issues, newly formed states were combined back with their original states to ensure a comprehensive historical record and to avoid any significant decline in GDP that might result from the establishment of new states. In addition, states with small populations were excluded from consideration. A population cut-off of 5 million, based on the 2011 Indian census, was applied to determine which states to exclude from the analysis. As a result, a total of 14 states were omitted due to their populations being below this threshold. The final list of included states is shown in Table 4.1.

Table 4.1: Included Indian States



Fiscal Variables

All fiscal variables at the state level were expressed as a percentage of GDP. This approach ensures that different fiscal variables are comparable across states and minimizes the differences associated with the varying sizes of the states. The study covered the data period from 1995 to 2019. Due to the significant impact of the Coronavirus pandemic on the global economy, the period from 2020 to the present was excluded. The fiscal data was reviewed, cleaned, and transformed.

The GDP data in this study have been re-based using a consistent reference year of 2011. This approach provides a uniform measure for comparison over time and takes into account inflation and other economic changes. All historical fiscal data for each Indian state, sourced from the Reserve Bank of India (RBI), are presented in Table 4.2. Total revenue is an aggregation of tax revenue and non-tax revenue. Non-tax revenue includes both the states' non-tax revenue and intergovernmental transfers, which are generally granted from the Central Government.



Table 4.2: Fiscal Variables from RBI

	Power sector • Economic services expenditure • Non-tax revenue • Taxes and duties on electricity • Power project disbursements
	Transport sector • Economic services expenditure • Road transport sector non-tax revenue
	Other revenue variables • State's non-tax revenue • Grants from the Centre • Total non-tax revenue • Total tax revenue • Total revenue
	Expenditure variables • Relief on account of natural calamities – developmental expenditure • Social services – developmental expenditure • Total expenditure
	Capital receipts & disbursement • Internal debt (receipt) • Total capital disbursements
	Other variables • State GDP • Consumer price index (state and national)

Figures 4.1 and 4.2 show how each disaggregated variable flows through to a state's aggregated fiscal variables.

Figure 4.1: Expenditure Variables Flow Diagram

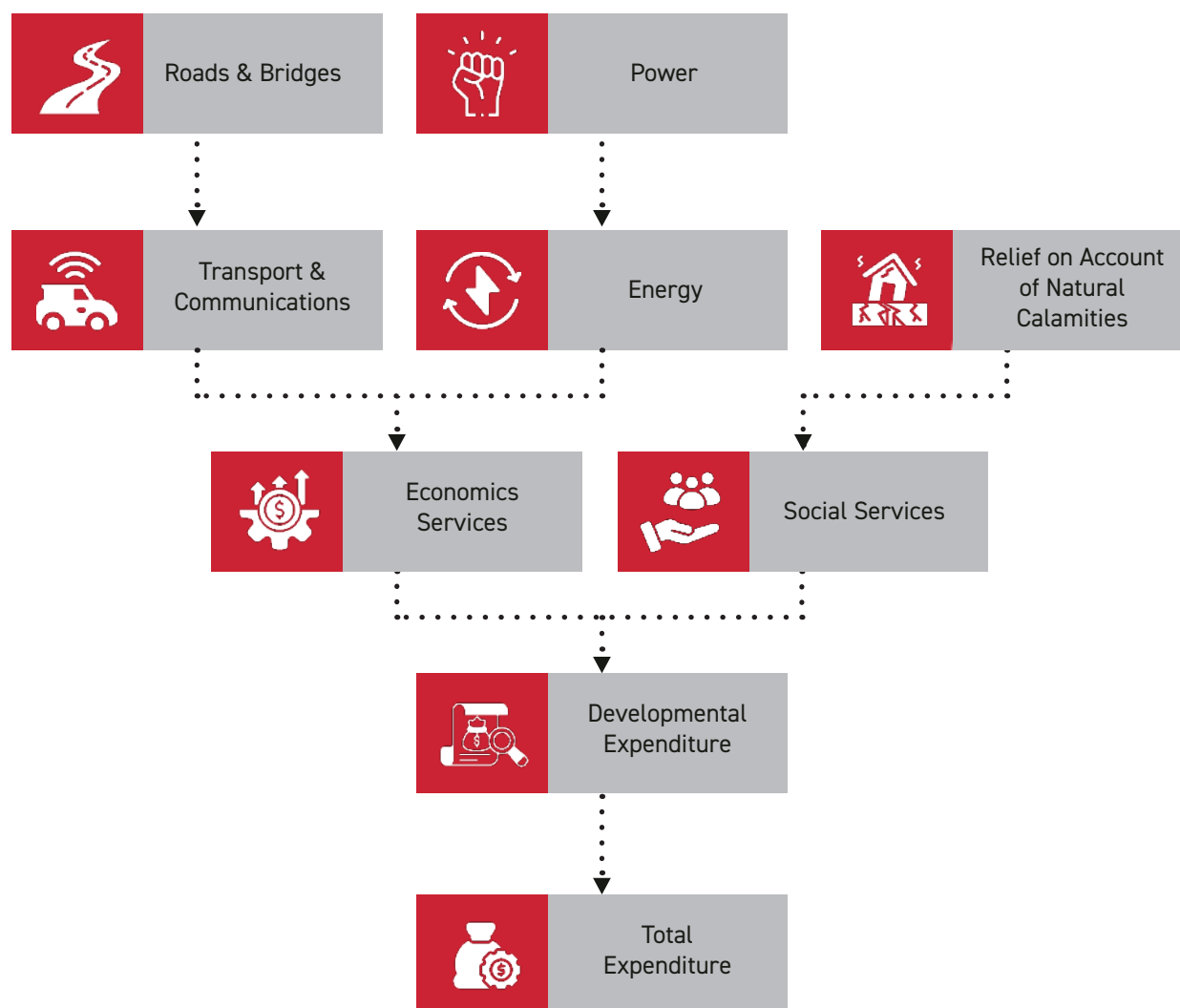
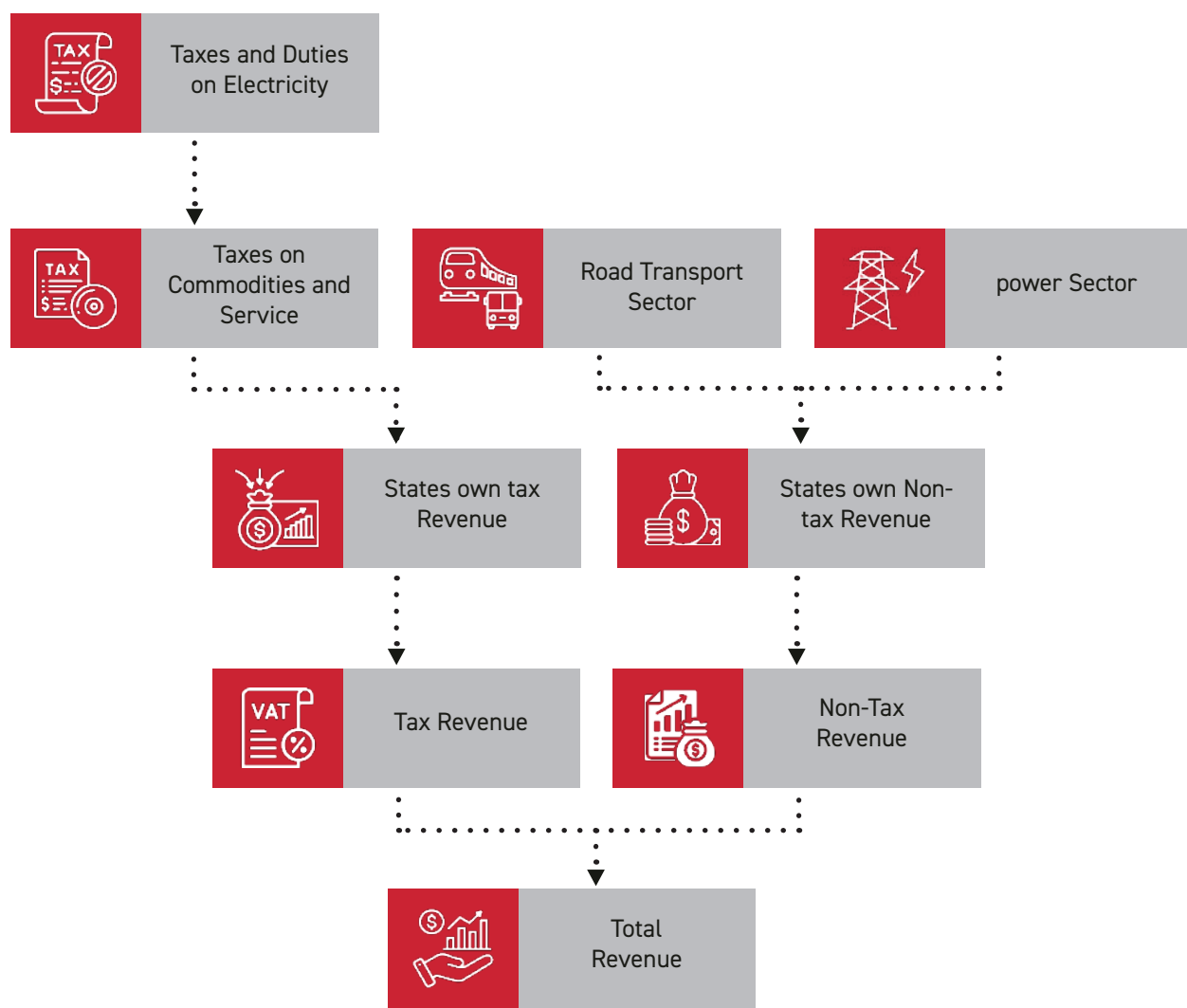


Figure 4.2: Revenue Variables Flow Diagram



As a panel model requires stationary data, the fiscal variables were tested to determine if they were stationary or non-stationary. Non-stationary data refers to a time series whose statistical properties, such as mean, variance, and autocorrelation, change over time. This characteristic can pose significant challenges for econometric modelling (Brockwell and Davis 2002). The tests revealed that the fiscal variables were non-stationary. As a result, all fiscal variables underwent first-order differencing, a process that effectively transformed the dataset into a stationary time series.

Disaster Intensity Variable

The data on disaster events for this study were obtained from two primary sources: the EM-DAT International Disaster Database and the Central Water Commission (CWC). The time period covered by the disaster data matched that of the fiscal data, spanning from 1995 to 2019. Both datasets provided the following statistics, which were used in the study:



To determine state-level data on disasters, each event was allocated to a state based on the affected districts or places. For cyclone-related losses, these were specifically allocated to coastal states. In cases where a cyclone affected multiple coastal states, the state with the highest impact was determined by checking the cyclone's path and its corresponding Wikipedia page. The losses were then attributed to that state. For flooding data, information from the Indian CWC was used. This dataset, a yearly dataset that spans from 1953 to 2020, compiles all state-wise flood-related damage, summed up annually.

Life Years Lost Calculation

The disaster intensity variable used in our panel model is based on the 'Life Years Lost' (LYL) measure. The total monetary damage from a disaster is correlated with both its severity and the income and asset values of the impacted population, which makes this measure challenging to compare across different regions and countries. By incorporating data on the number of fatalities and people impacted, the LYL provides a more standardized measure of disaster severity. As an index, the LYL facilitates better comparisons across different types of disasters and regions. Noy (2016a) adapted the equation for disaster intensity and provided the following formula, which was used to calculate the LYL.

Equation 2: Life Years Lost equation

$$LifeYearsLost = M \cdot (A^{\text{expec}} - A^{\text{median}}) + e^{TN_{EMDAT}} + \frac{(1 - c)Y}{GDP_{pc}}$$

Source: Noy (2016a)

The first component of the LYL calculation is the fatality component. The World Health Organization's (WHO) Disability Adjusted Life Years (DALY) of 92 years was used for A^{expec} , while the median age for each state was used as per the 2011 census. M is derived from the number of fatalities from a given disaster. This helps measure the productive capacity lost for each individual who dies in a disaster.

Equation 3: Mortality Component of LYL Equation

$$M \cdot (A^{\text{expec}} - A^{\text{median}})$$

The next component relates to the cost function associated with the affected population, as illustrated in Equation 4. e represents the welfare reduction function, for which a value of 0.054 was employed, consistent with Noy (2016a) and the WHO's index. The variable T denotes the time it takes for an affected person to return to normalcy or for the impact of the disaster to subside, while the N^{EMDAT} term refers to the number of affected individuals, as reported in the EM_DAT database.

Equation 4: Cost Function Associated with the Population Affected

$$eTN^{\text{EMDAT}}$$

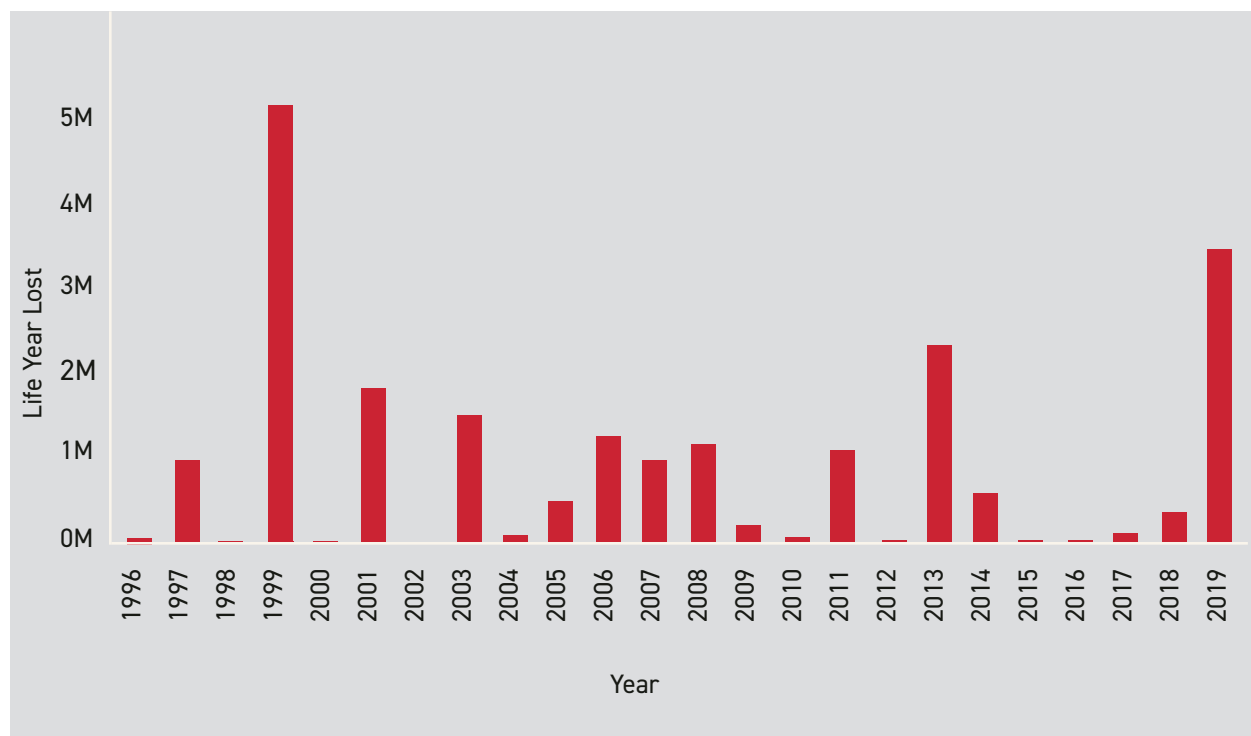
The final component of the LYL model is related to the financial losses associated with the disaster. The variable e denotes the discount factor, with the benchmark specification of the index utilizing a discount rate of 75 percent. This rate is consistent with the findings of Noy (2016a) and is employed in this study. Additionally, the variable Y represents the financial losses incurred due to the disaster, while GDP_{pc} signifies the GDP per capita for the state.

Equation 5: Equation Associated with The LYL due to Damages to Physical Capital and Infrastructure

$$\frac{(1 - c)Y}{GDP_{pc}}$$

Figure 4.3 shows the LYL value per year for Odisha from 1996 to 2019. The highest values represent events with the highest severity in terms of fatalities, the number of people affected, and total monetary damage. The severity of disasters varies substantially from year to year, with an average LYL of 84,000 and a standard deviation of 2 million. The most severe events during the data period were the Odisha Super Cyclone in 1999 (4.9 million LYL) and Cyclone Fani in 2019 (3.6 million LYL).

Figure 4.3: Odisha Life Years Lost per Year

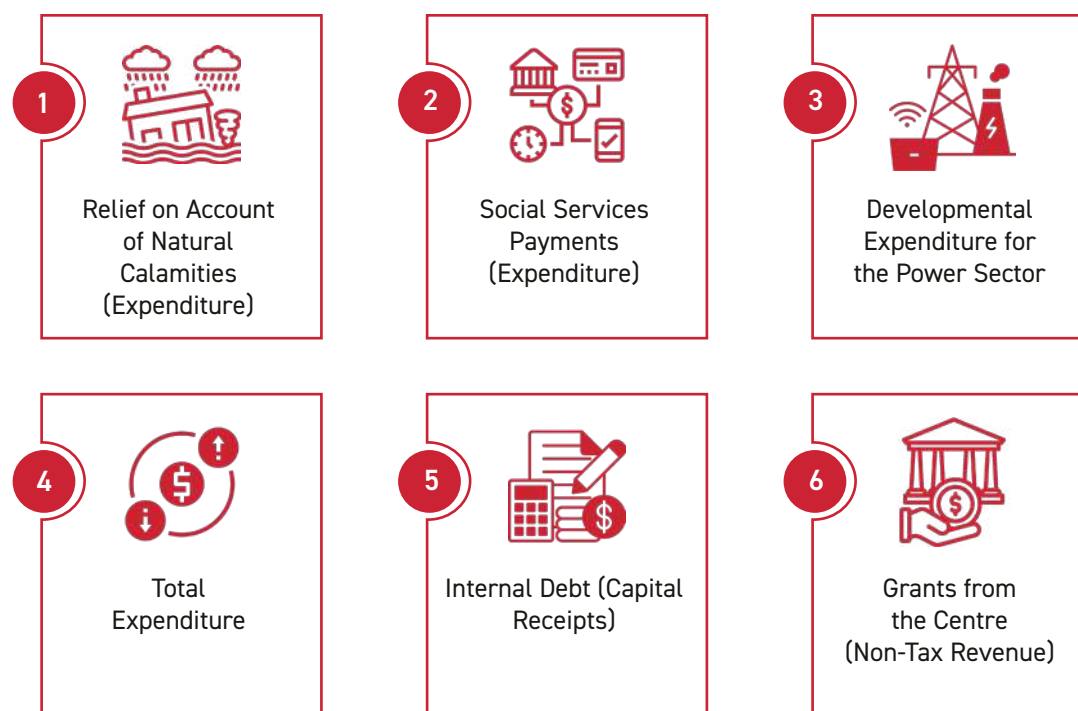


The LYL values in the figure above illustrate the human and economic severity of disasters. These peaks validate the modelling approach and its significance in forecasting fiscal risk, which is a core objective of this study.



Economic Modelling Results

The economic modelling revealed a significant increase in fiscal spending and a decline in Odisha's internal debt position following a disaster. However, not all fiscal variables modelled were significantly impacted. The fiscal variables that showed significant impacts from disasters were the following:



The other fiscal variables modelled did not show a significant impact from the LYL disaster variable (at the 5 percent level). Table 4.3 shows the coefficients for LYL for each of the fiscal variables that were found to be statistically significant in the panel model.

A time lag of 1 year and 2 years was included in the panel model to examine whether the impacts persisted in the short term. The results for the time lag indicators were not significant, indicating that most of the impact was experienced in the year the disaster occurred and was reflected in the fiscal variables for the following year.

Figure 4.3: Coefficients and Significance (P-Value) for Each Fiscal Variable Where There Was a Significant Effect

Fiscal variable	LYL coefficient	P-value	Standard error
Relief on account of natural calamities	2.182155e-09	1.181e-08	3.7437e-10
Social services	3.480725e-09	5.245e-06	7.5343e-10
Debt	4.769941e-09	0.0052	1.6974e-09
Total expenditure	8.873447e-09	1.576e-05	2.0289e-09
Grants	3.18e-09	0.0026	1.0481e-09

Average Modelled Fiscal Impact

The tables below show the modelled impacts for both an average-intensity disaster and a disaster with one standard deviation above average intensity. The results are expressed in terms of monetary value for the fiscal variable and as a \$ percentage. These percentage values can help estimate the future impact in \$ if these fiscal variables are projected in the future. Additionally, a 95 percent confidence interval is included for each variable.

The modelling indicated that total expenditure, relief efforts related to natural calamities, and spending on social services all significantly increase following a disaster. Additionally, there was a notable rise in Odisha's internal debt, suggesting that the government may resort to borrowing to meet the heightened spending demands. The model also showed that the states' non-tax revenue remained relatively unchanged, while grants from the central government significantly increased following a disaster. This implies that the Indian Central Government consistently provides support to the Odisha Government in the aftermath of disasters, beyond the funding received from the National Calamity Relief Fund.

The coefficients displayed in Table 4.4 indicate how each fiscal variable changes in response to different LYL. However, the impacts of a disaster can lead to a wide range of values for LYL. For example, the historical average (mean) LYL for disasters in Odisha is 84,000. Using this average, Table 4.4 presents the corresponding percentage changes for each fiscal variable following a disaster of average intensity.

Figure 4.4: Percentage Change in Odisha's Fiscal Variables Following an Average-Intensity Disaster

Fiscal variable	Average change following a disaster (% of fiscal variable)	95% confidence interval
Relief on account of natural calamities	0.02%	+/- 0.007%
Social services	0.03%	+/- 0.014%
Debt	0.05%	+/- 0.032%
Total expenditure	0.09%	+/- 0.039%
Grants	0.03%	+/- 0.019%

The values presented reflect changes in fiscal variables that help analyze their impact in \$. Table 4.5 illustrates these figures in \$ based on the 2022 value of the modelled fiscal variable. As these fiscal variables evolve in the future, the percentage changes will provide insights into how their impact shifts with variations in fiscal values. Following an average disaster, total expenditure is expected to rise by \$80.5 million, partially offset by Central Government grants amounting to \$5.3 million. Additionally, spending on social services is expected to increase by \$13.2 million, while internal debt issuance is anticipated to grow by \$2.2 million.

Figure 4.5: Monetary Change in Fiscal Variables (\$) in Odisha from an Average-Intensity Disaster

Fiscal variable	Average change following a disaster (\$)	95% confidence interval
Relief on account of natural calamities	446,952	+ - 150,288
Social services payments	13,192,116	+ - 5,596,848
Developmental expenditure on power	3,048	+ - 2,868
Total expenditure	80,529,396	+ - 36,089,328
Internal debt issuance	2,239,152	+ - 1,561,752
Grants from the Centre	5,338,056	+ - 3,448,164

The figures presented reflect changes in fiscal variables for an average severity event in Odisha; however, the impacts of hazards can vary significantly. The LYL data shows a wide range because it includes several extreme events with very high LYL values. To better illustrate the range of impacts, Table 4.6 shows the percentage change in fiscal variables for a disaster that has a severity one standard deviation above the average severity in Odisha. This level of severity corresponds to approximately 212000 LYL.

Modelled Fiscal Impact of High Severity Disasters

Tables 4.6 and 4.7 present the modelled impacts of two of the most severe events that have occurred in Odisha. These events are the 1999 Odisha Super Cyclone, which has an estimated return period of 50 years, and Cyclone Fani, with an estimated return period of 26 years (Chittibabu et al. 2004). The results are shown in terms of both the percentage change in the fiscal variables and their corresponding monetary value in \$, based on the values of these fiscal variables in 2022. A 95 percent confidence interval is also provided.

The LYL values for both events were much higher than average: 4.9 million LYL for the Odisha Super Cyclone and 3.6 million LYL for Cyclone Fani. These values were used to calculate the potential effect on fiscal variables if a similar event were to strike Odisha in 2022.

If an event as severe as the 1999 Odisha super cyclone were to occur today, the projected increase in total expenditure would be \$467.7 million. This includes an additional \$76.6 million for social services and a \$2.6 million increase in relief payments. Odisha's internal debt issuance would also increase by \$13.0 million, while Central Government grants would increase by \$31.0 million.



Figure 4.6: Percentage Change in Odisha's Fiscal Variables in a Year Which Suffers a Disaster One Standard Deviation above the Average Severity

Fiscal variable	Change for a disaster 1 standard deviation above the average (% of fiscal variable)	95% confidence interval
Relief on account of natural calamities	0.54%	0.180%
Social services payments	0.85%	0.362%
Developmental expenditure on power	0.63%	0.594%
Total expenditure	2.18%	0.975%
Internal debt issuance	1.17%	0.816%
Grants from the Centre	0.78%	0.504%

The projected total expenditure in the event of a severe occurrence like the 2019 Cyclone Fani today is estimated at \$338.9 million. This includes \$55.5 million in spending on social services and an additional \$1.9 million for relief payments. Furthermore, Odisha's internal debt issuance is expected to rise by \$9.4 million, while Central Government grants would increase by \$22.5 million (see Tables 4.9 and 4.10).

Figure 4.7: Percentage Change in Odisha's Fiscal Variables if an Event Equivalent to the Odisha Super Cyclone Occurred in 2022

Fiscal variable	Change in fiscal variables (%)	95% confidence interval
Relief on account of natural calamities	1.2%	+ - 0.415%
Social services payments	2.0%	+ - 0.836%
Developmental expenditure on power	1.5%	+ - 1.370%
Total expenditure	5.0%	+ - 2.251%
Internal debt issuance	2.7%	+ - 1.883%
Grants from the Centre	1.8%	+ - 1.163%

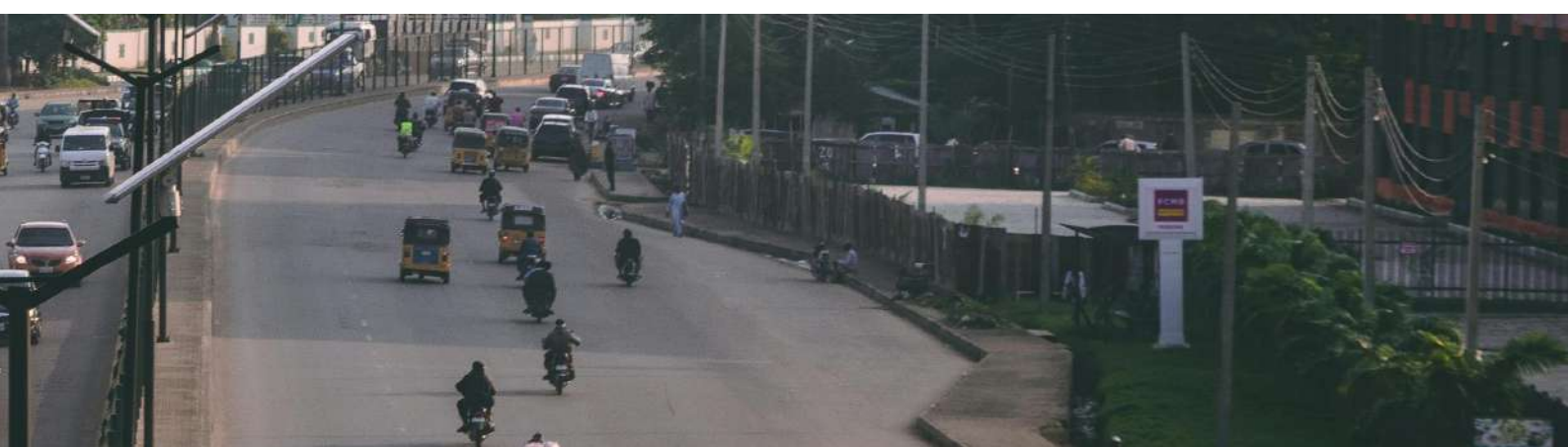


Figure 4.8: Monetary Change in Fiscal Variables (\$) in Odisha if an Event Equivalent to the Odisha Super Cyclone Occurred in 2022

Fiscal variable	Change in fiscal variable (US\$)	95% confidence interval
Relief on account of natural calamities	2,595,921	872,897
Social services payments	76,620,516	32,506,812
Developmental expenditure on power	17,712	16,680
Total expenditure	467,718,900	209,608,680
Internal debt issuance	13,005,108	9,070,704
Grants from the Centre	31,003,716	20,027,100

Figure 4.9: Percentage Change in Odisha's Fiscal Variables if an Event Equivalent to Cyclone Fani Occurred in 2022

Fiscal variable	Change in fiscal variable (%)	95% confidence interval
Relief on account of natural calamities	0.9%	+/- 0.30%
Social services payments	1.4%	+/- 0.61%
Developmental expenditure on power	1.1%	0.99%
Total expenditure	3.6%	1.63%
Internal debt issuance	2.0%	1.36%
Grants from the Centre	1.3%	0.84%

Figure 4.10: Monetary Change in Fiscal Variables (\$) in Odisha if an Event Equivalent to Cyclone Fani Occurred in 2022

Fiscal variable	Change in fiscal variable (\$)	95% confidence interval
Relief on account of natural calamities	1,881,192	632,568
Social services payments	55,524,720	23,556,768
Developmental expenditure on power	12,828	12,084
Total expenditure	338,942,688	151,897,500
Internal debt issuance	9,424,440	6,573,288
Grants from the Centre	22,467,516	14,513,076





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 to understand how return periods evolve over time. This understanding is crucial to ensure that disaster risk management plans remain effective and meet current needs. By modelling potential costs ahead of a major disaster, we can more effectively plan and prepare for such events. This includes analyzing the breakdown of losses that contribute to disasters, which allows for a more tailored DRF strategy.

This section of the report presents the results of the catastrophe modelling conducted to assess the anticipated impact of disasters on the power and road sectors, as well as their subsequent effects on the fiscal health of the state.



Hazard Model

In the catastrophe modelling for Odisha, four types of hazards were analyzed: earthquakes, tropical cyclones, floods, and landslides. These natural hazards are represented as a collection of events. Each event is a single manifestation of the hazard (i.e., one tropical cyclone) that produces some intensity at the location of the infrastructure elements and has some probability of occurrence. The complete set of events — such as all the simulated tropical cyclones — thoroughly represents the potential occurrences of each hazard.

Climate Models

As part of climate modelling, multiple projections from Global Circulation Models included in Coupled Model Intercomparison Project Phase 6 (CMIP6) have been validated. These projections incorporate anthropogenic forcing, represented by a combination of SSP (shared socio-economic pathways) and RCP (representative concentration pathways), as defined by the Intergovernmental Panel on Climate Change (IPCC) in its Sixth Assessment Report (AR6). Hydrometeorological phenomena are modelled based on meteorological forcing such as precipitation and temperature from a historical period, known as the base climate, which corresponds to the period 1980-2010. This period serves as a recent 30-year climate norm. To adapt the base climate to future scenarios, climate projections are used to estimate the Delta method. This method adjusts the meteorological factors in the base climate to align with the 30-year average expected in a projected future climate. From this modified forcing, hydrometeorological hazards are recalculated.

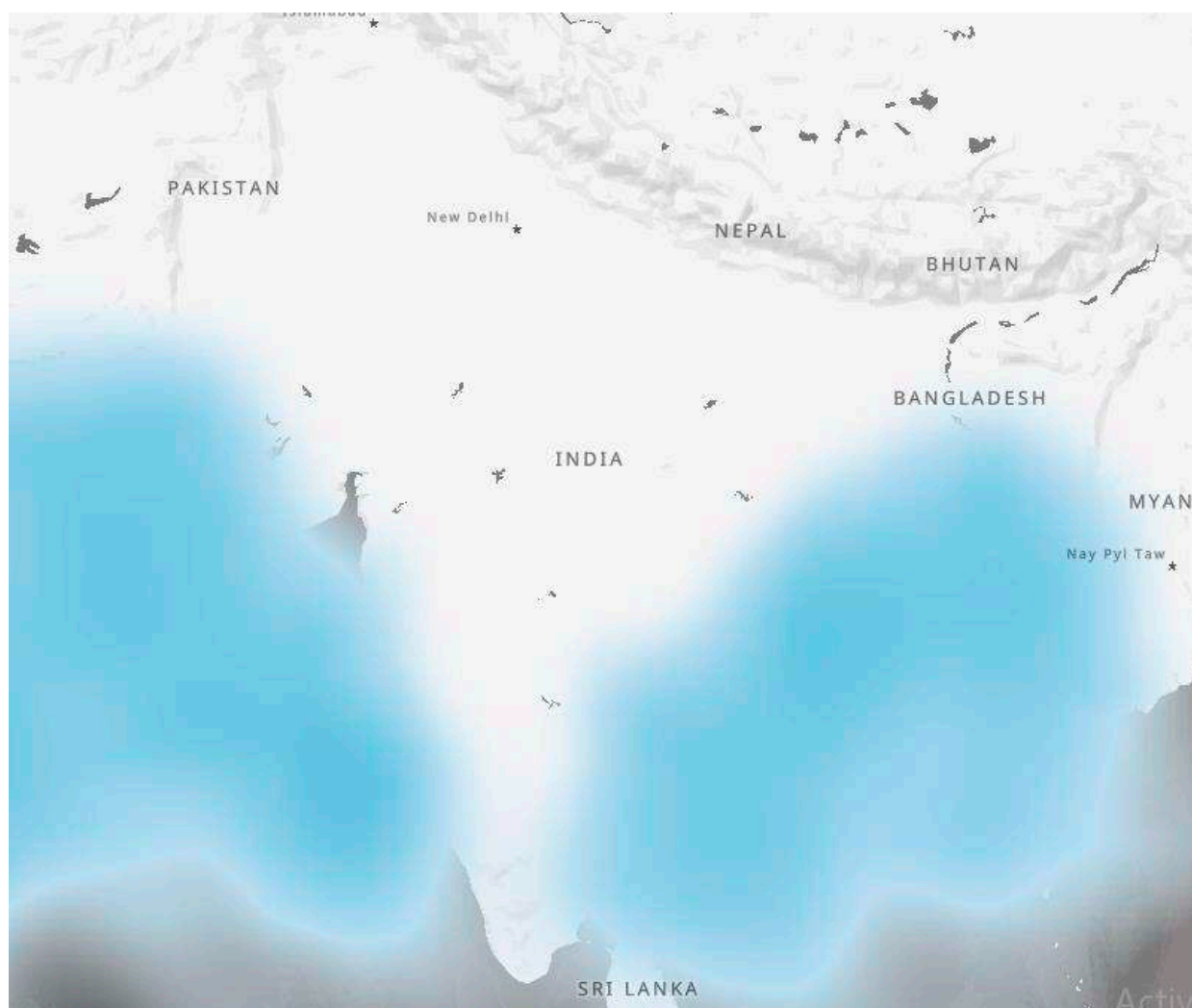
Tropical Cyclone Hazard Model

Cyclogenesis is a mesoscale process that requires high-resolution inputs from climate models. This section used four high-resolution models: CMCC-CM2-VHR4, CNRM-CM6-1-HR, EC-Earth3P-HR, and HadGEM3-GC31-HM. These models focus exclusively on an emissions scenario of SSP5-RCP8.5. Consequently, for tropical cyclones, the model is constructed based on a single trajectory, rather than two bounds of climate variation, as is done for the other hydrometeorological hazards.

For this study, the tropical cyclone hazard was updated, including the latest cyclone trajectories up to 2024. The method was implemented in the CAPRA ROBOT software module TCHM (Bernal and Cardona 2018). Hazard assessment for both strong winds and storm surges was assessed for this project using an updated catalogue that includes 155 historical tropical cyclones for the North Indian Ocean basin. The completeness periods were recalculated to determine the occurrence frequency of these historical cyclones. For each historical track, a family of associated 'children' tracks was generated using a bi-dimensional Wiener process. Strong wind speed and storm surge flooding were calculated for each cyclone child track, and the results were utilized to compute the probability moments of wind speed and coastal flooding for each historical track.

The results are presented for strong winds in terms of the geographical distribution of peak wind speed from 3-second gusts, and for storm surge, as the distribution along 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 result is a set of probabilistic wind fields and storm surge flood data. Figure 5.3 shows the map of a 500-year return period of strong winds for India.

Figure 5.3: Wind Hazard from Cyclones in India, 500-Year Return Period



Note: The intensity is represented by wind velocity in km/h.

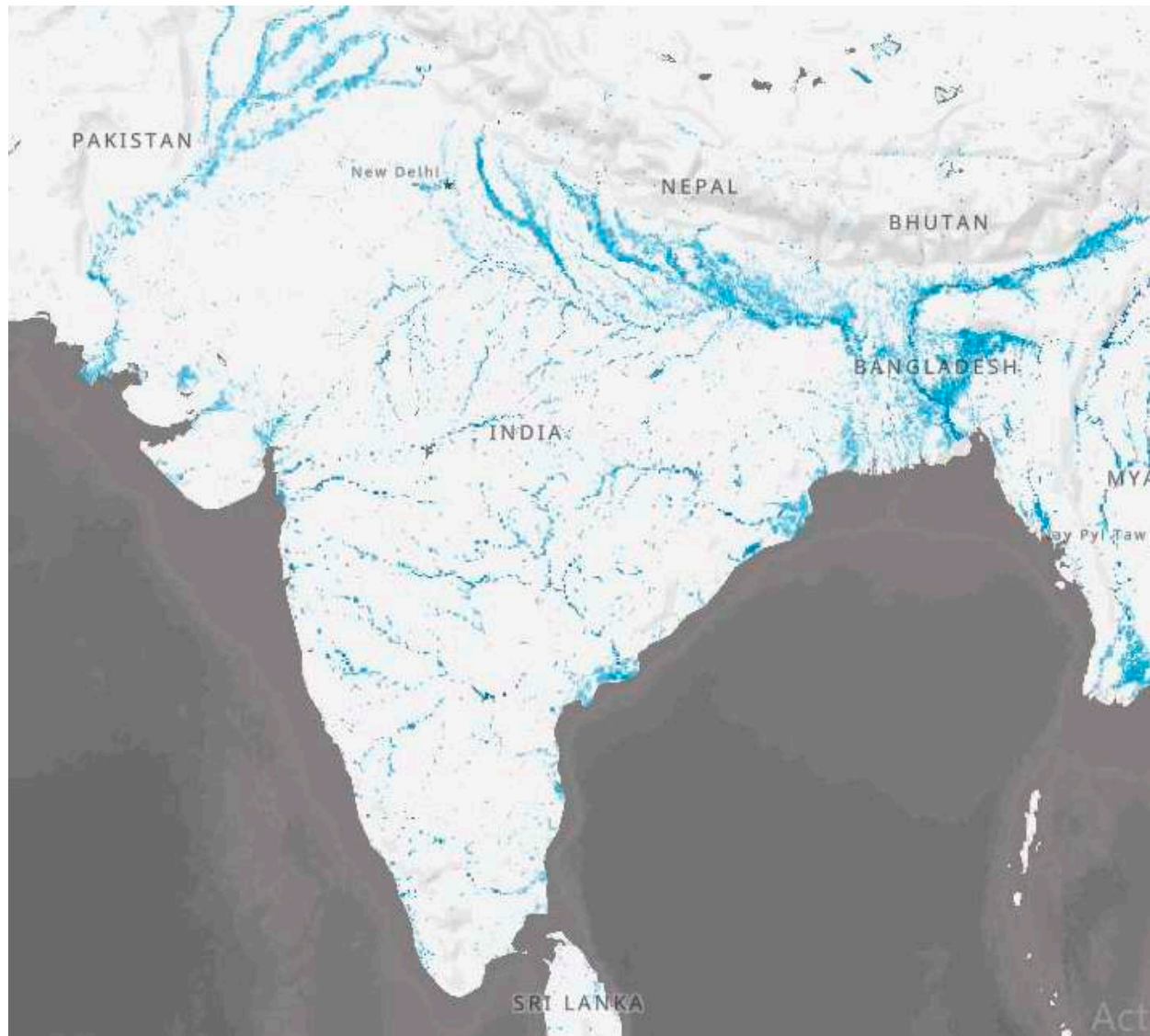
Flood Hazard Model

For flood hazard modelling, the global flood hazard model developed by Alfieri et al. (2023) was used. The model defines the inflows to various sections of the tributary basin upstream of different points along the main rivers and streams. It hydraulically stimulates the movement of these flows within the channels, with varying inflows depending on the sub-basins that contribute to the main channel basin. In this way, and at an intermediate resolution, it is possible to cover all the rivers in the country and determine flood areas and depths caused by overflow.

The magnitude of flood discharge is estimated using methods that rely on statistical analysis of data from the hydrological region. In this case, regional frequency analysis was implemented. This methodology involves analyzing statistical data from a homogeneous region, which is identified using the index flood method (IFM). This approach aims to estimate flood frequency at the site with the highest possible confidence, even for quantiles that occur with very low frequencies. Once the discharge quantiles are determined, these results are input into a simplified hydraulic flood model. The model then generates hydraulic cross sections, where the flood stage is calculated from the flow value by solving the Manning

equation. These stages are interpolated based on the local relative morphology, and modifications are included to account for longitudinal hydraulic connectivity between sections, especially in large flood plains. Figure 5.1 presents the uniform flood hazard map for a 100-year return period for India. This spatial analysis contextualizes Odisha's flooding exposure within the broader national context, supporting targeted mitigation strategies for flood-prone infrastructure.

Figure 5.1: Flood Hazard Map for A 100-Year Return Period for Present Climate Conditions in India

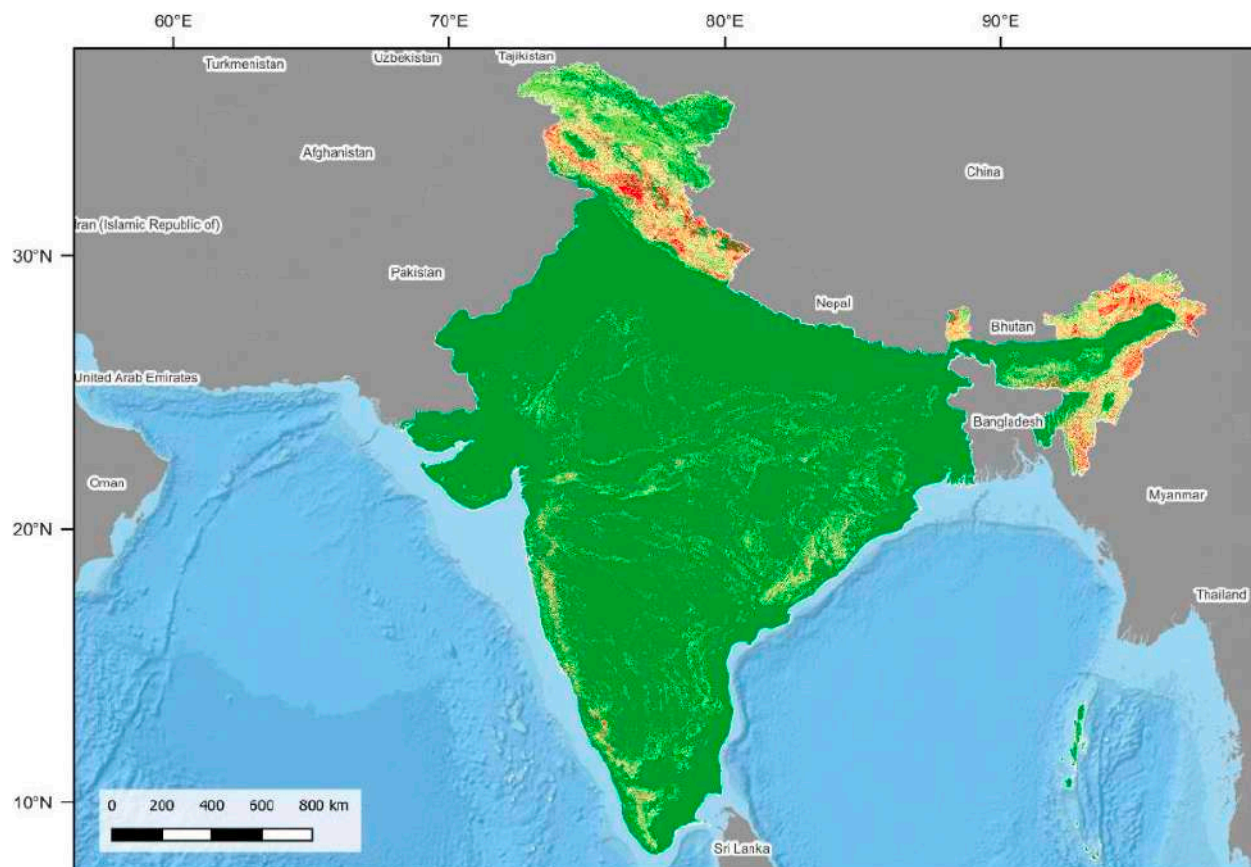


Landslides Hazard Model

The global susceptibility model and rainfall thresholds developed by Palau et al. (2023) were utilized, along with the landslide hazard model developed by Cardona et al. (2023). The spatial resolution of this model is appropriate for this assignment. Susceptibility is modelled heuristically, taking into account factors such as slope, lithology, vegetation cover, and soil moisture. Each of the previously mentioned characteristics is mapped to a susceptibility factor (an integer number between 0 and 5). These factors are then weighted according to their expected influence on the susceptibility. The result is the weighted sum of the characteristics present at each mountainous location within the territory. Local modifiers, such as population density or road density, are included to account for the

anthropogenic influence on landslides. The resulting susceptibility is mapped with a spatial resolution of 30 m and is expressed as an integer value between 0 and 5. More information about the model can be found in Palau et al. (2023). Figure 5.2 shows the landslide susceptibility map for India.

Figure 5.2: Landslide Susceptibility of India



Source: Nadim et al. (2023)



Landslide hazard depends not only on susceptibility but also on triggering factors, which are external forces that locally increase instability, triggering a landslide event. In this study, the primary triggering factors examined are excessive rainfall and seismic acceleration. The rainfall trigger is derived directly from climate modelling, while the earthquake trigger is simulated based on a seismic hazard model. Nonetheless, to set the corresponding triggering intensity, specific landslide thresholds are required. In this assignment, we will utilize the thresholds proposed by Palau et al. (2023), as 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
$0.05 \leq \text{PGA} < 0.15$	0%	0%	0%	0%	0%
$0.15 \leq \text{PGA} < 0.25$	0%	1%	2%	3%	5%
$0.25 \leq \text{PGA} < 0.35$	0%	2%	3%	5%	10%
$0.35 \leq \text{PGA} < 0.45$	0%	3%	5%	10%	15%
$\text{PGA} \geq 0.45$	0%	5%	10%	15%	20%

Source: Nadim et al. (2023)

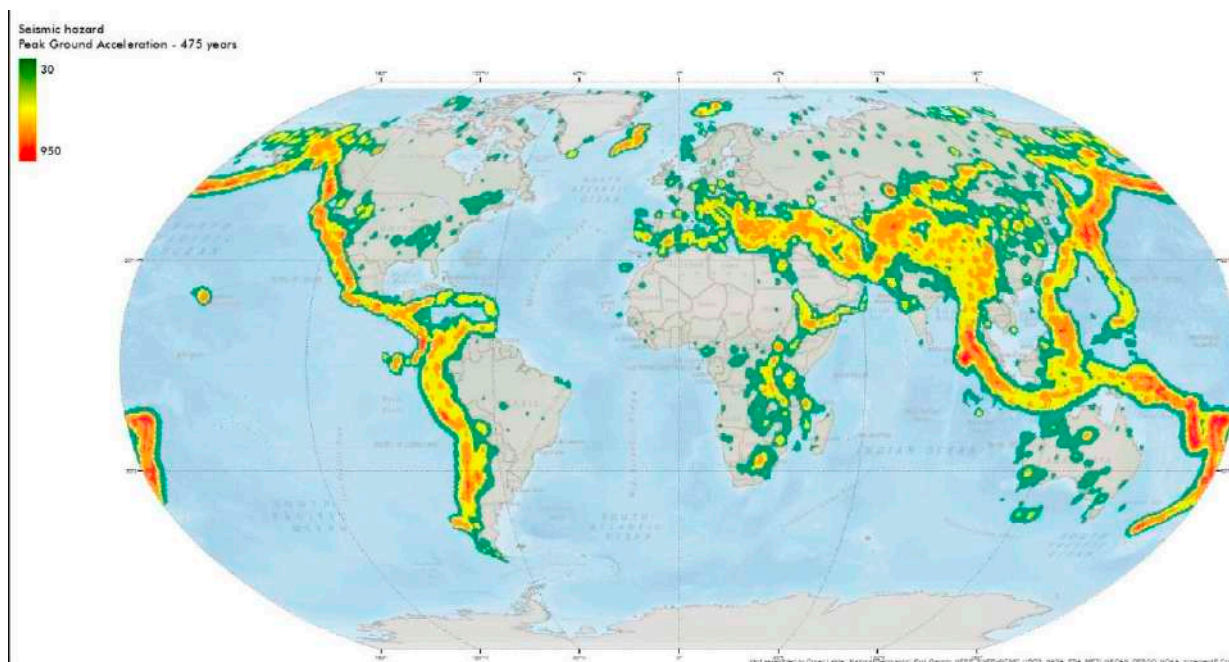
The model estimates the probability of landslides based on susceptibility and thresholds in response to simulated triggering events, such as rainfall or seismic acceleration. It should be noted that landslides are assumed to be an event of very high local energy, which means that the vulnerability of any exposed element is maximized, leading to total loss. Therefore, vulnerability functions for this phenomenon have not been developed.

Seismic Hazard Model

Seismic hazard is not influenced by climate and is, therefore, considered a stationary phenomenon. For the FRA of Odisha, the global seismic hazard model developed by Cardona et al. (2014) was used. The spatial resolution of this model is appropriate for this assignment. This section presents a general overview of the model.

The seismic hazard at the bedrock level is calculated based on historical information recorded in seismic catalogues. Using information related to the magnitude and the location of the hypocentre of each earthquake, the intensity of the events is calculated by a set of stochastic scenarios, mutually exclusive and collectively exhaustive, each with a geographical distribution of probability. During this evaluation, the attenuation of the seismic energy with distance is taken into account for the area surrounding each event. This evaluation thus gives us a curve of the probability of exceeding certain levels of acceleration at a specific point where exposed assets may be affected. Given that the said curve is obtained for each one of the points within the calculation grid, it allows for the creation of seismic hazard maps that correspond to various spectral ordinates and return periods. This means the maps reflect the dynamic structural response characteristics of the exposed structures. This input is fundamental for conducting a probabilistic risk assessment of the inventory of exposed elements in countries that face seismic hazards. An in-depth description of the seismic hazard model can be found in Cardona et. al. (2014). Figure 5.4 shows an example of a seismic hazard map calculated for a 475-year return period of peak ground acceleration at bedrock level (i.e., $V_{s30} = 1,100$ m/s). (Note: V_{s30} represents the shear wave velocity within the top 30 m below the surface. This parameter is commonly used to assess the subsurface materials' stiffness.)

Figure 5.4: Seismic Hazard Map for Peak Ground Acceleration and 475-Year Return Period



Exposure Model

The database of exposed elements refers to the collection of physical elements that constitute an infrastructure system. For each element, three essential properties are established: geographic location, physical value (or replacement cost of the asset), and a structural or archetypal classification that relates to its vulnerability. It is common that some, or even all, of the three fundamental characteristics may be unavailable in the existing data within a country. Therefore, it becomes necessary to make estimates to create an approximate inventory of exposed elements. In this assignment, the focus on exposure for Odisha is limited to the Energy and Roads sectors.

Energy Sector

In this assignment, the term 'energy sector' refers to the existing infrastructure involved in the generation, transmission, and distribution of electricity within the territory. Notably, oil and gas infrastructure, which some authors include as part of the energy sector, is not considered in this context.

The energy sector is, therefore, divided into three subsectors: generation, transmission, and distribution. Each subsector requires an independent exposure model that takes into account its unique characteristics. For example, elements in the generation subsector typically include power plants that are extremely diverse in terms of the type of energy converted, the plant capacity, or the components that make up the facility. 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 complexity makes the energy sector one of the most complex areas for conducting risk assessments.

According to data from the World Resources Institute (WRI) and Open Street Map (OSM), more than 5,000 MW of installed generation capacity is distributed across eight different types of energy conversion, as shown in Table 5.3. In terms of transmission, Odisha has more than 4,000 km of transmission lines. Table 5.4 displays the total length of transmission lines categorized by their different operational voltages.

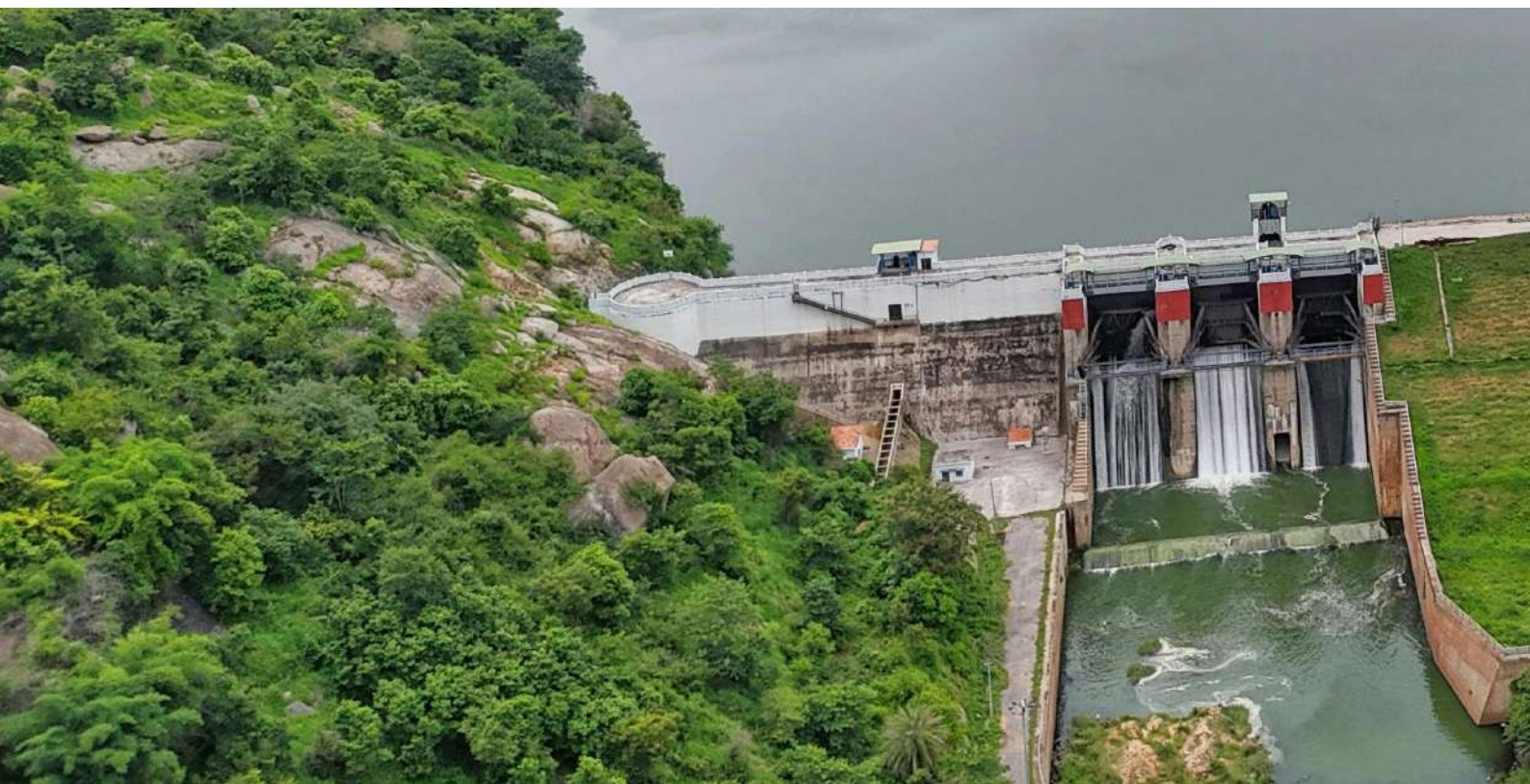


Table 5.3: Installed Capacity of the Generation Sector in Odisha

Source energy	Capacity [MW]	[-]
Bioenergy (biomass, waste, etc.)	121	2.2%
Coal	600	11.1%
Gas	904	16.7%
Hydro	2,435	45.1%
Oil (petroleum derivatives)	369	6.8%
Other	753	13.9%
Solar (photovoltaic)	216	4.0%
Wind	3	0.1%
Total	5,401	

Table 5.4: Transmission Line Voltages and Lengths in Odisha

Voltage (kV)	Length	[-]
<110	476	11.4%
110 - <220	1,610	38.5%
220 o >220	2,096	50.1%
Total	4,182	



Generation

The estimated replacement cost for the exposed elements in the generation subsector is based on information from the Global Power Plant Database (WRI) and the Power Plant Database (OSM). The following section outlines the procedure used to estimate the cost of generation infrastructure.

Initially, the raw data is processed by removing elements that do not provide information about energy sources or generation capacity. Next, the data concerning energy sources is reclassified into one of the basic categories, as outlined in Table 5.5. Next, the capacity of each plant is verified using the available information. If data on a plant's capacity is missing, a value is randomly assigned based on a probability distribution of capacities for the same type of energy source (for more details, see Cardona et al. 2023). Finally, the replacement cost is determined using the cost indicators outlined by Cardona et al. (2023), which are defined by the IRENA Renewable Power Generation Costs 2023, and this cost is multiplied by the plant's capacity.

Table 5.5: Basic Energy Source Classes and Unitary Costs

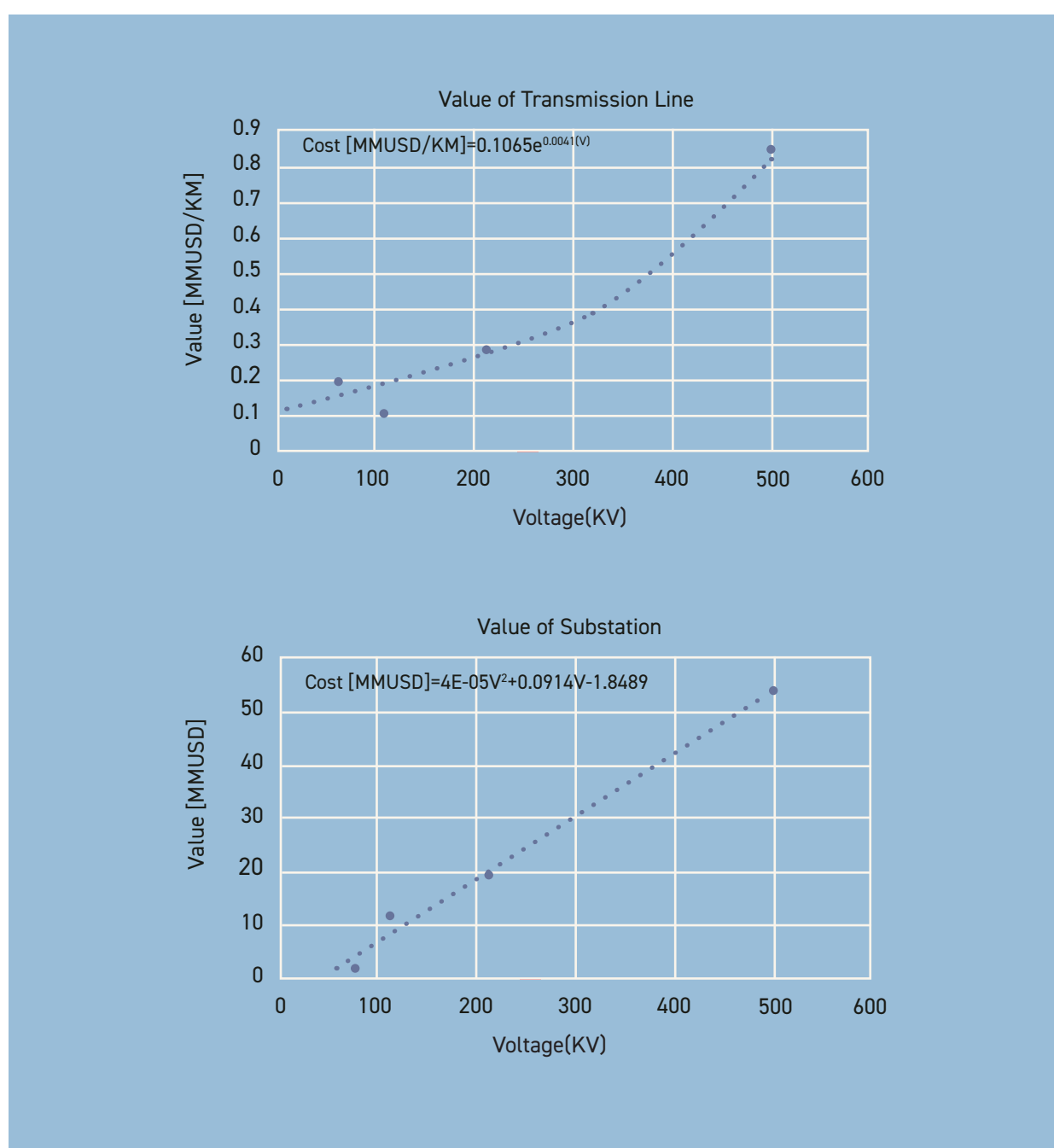
Source energy	Cost indicator (\$/kW)
Bioenergy (biomass, waste, etc.)	2,353
Battery (storage)	758
Coal	875
Gas	1,116
Geothermal	3,991
Hydro	2,135
Nuclear	3,782
Oil (petroleum derivatives)	795
Solar (photovoltaic)	857
Wave and tidal	7,038
Wind	1,325
Other	1,134

Source: Cardona et al. (2023)

Transmission

In the transmission subsector, raw data is gathered from the Power Lines Database and Power Substations Database, both provided by OSM. The following outlines the steps for estimating the cost of transmission infrastructure. For transmission lines, first, the length of each element is determined from raw spatial data. Long elements are then divided into segments of 150 m or less. The line voltage is then used to identify the cost indicator based on the price function proposed by Cardona et al. (2023). The overall cost of each segment is calculated by multiplying the corresponding cost indicator by the segment length. For substations, first, the raw data is debugged to eliminate substation elements that do not correspond to the transmission or distribution networks. Finally, the cost is evaluated based on the working substation voltage using the pricing function and presented in Figure 5.5.

Figure 5.5: Pricing Function Based on Transmission Line Voltage (Left) and Voltage at Substation (Right)



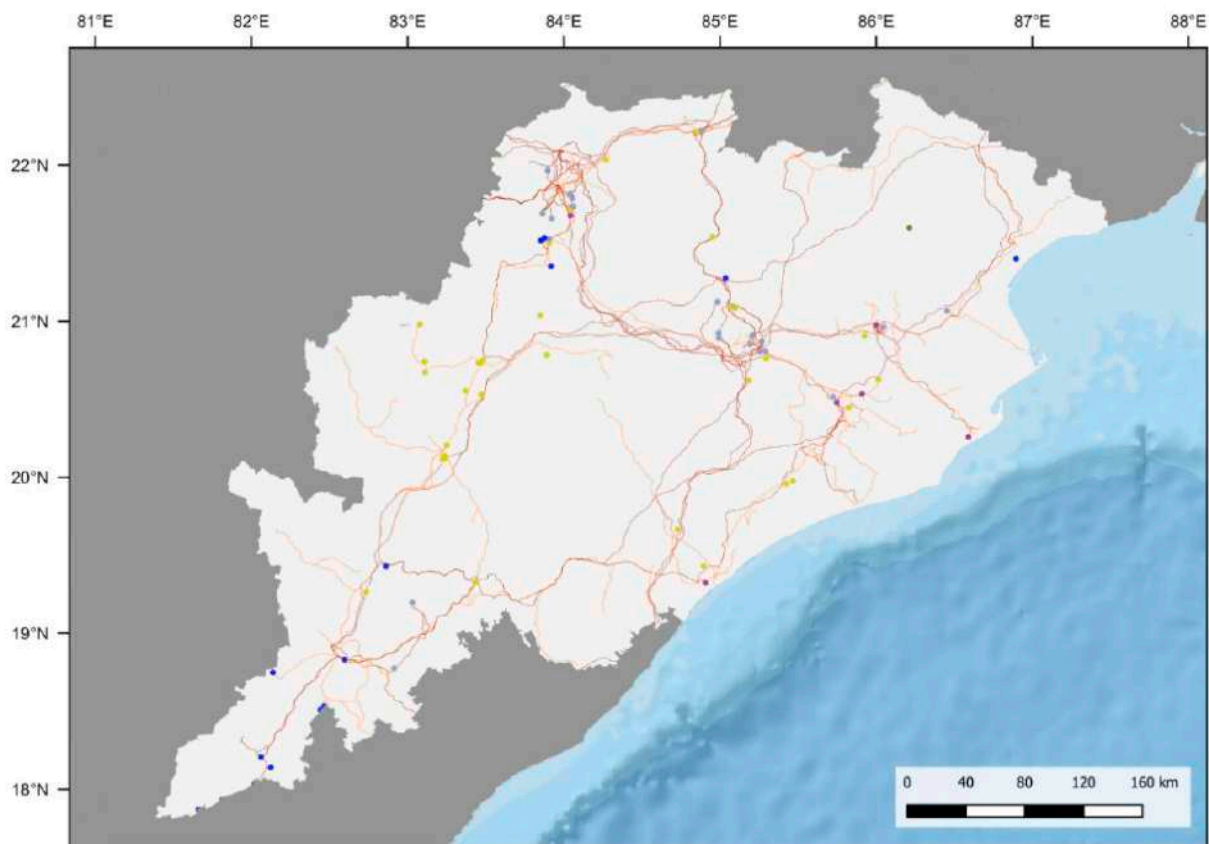
Distribution

Distribution networks are closely linked to population density. Generally, these networks are denser in areas with higher population concentrations and less dense in more sparsely populated regions. Furthermore, detailed information about the real location and characteristics of the distribution network such as cable posts, buried lines, and transformers - is often unavailable or non-existent. To address this issue, we apply the framework developed by Cardona et al. (2023) to create an exposure proxy for the distribution network based on population data. Additionally, we value the distribution subsector as a factor of the transmission subsector, using a factor of 2.26. This valuation process generates a total value that must be geographically distributed using the raster grid of population from the Global Human Settlements Layer (GHSL). This population grid is adjusted to reflect the number of individuals with access to electricity, based on data from the Indian census. As a result, areas with higher population density show greater exposure values, leading to an overall infrastructure value that aligns more closely with real access to electricity.

Exposure Database

The resulting exposure model is composed of geolocated vector entities that have attributes useful for risk evaluation. The replacement cost and the archetype of each element are included as key fields to characterize the exposure. Figure 5.6 shows a general overview of the sector for Odisha.

Figure 5.6: Map of the Exposure Database for Energy Sector in Odisha



Road Sector

The roads sector in this assignment refers to highway infrastructure, which includes expressways, national highways, state highways, major district roads, and bridges. Road infrastructure differs depending on design conditions such as topography, weather, and traffic. Furthermore, highway segments consist of many elements, such as pavement structure, retaining walls, gutters, box culverts, etc. A similar situation exists for bridges: each bridge is unique. Although they can be classified into archetypes, bridges are among the few infrastructure elements that do not conform to standard typification. In addition, the available data has significant limitations. It is important to note that no official data was received during the execution of this assignment. Therefore, the exposure model generated is only a reasonable approximation of the sector for the purpose of risk assessment.

According to the information in the OSM dataset, Odisha has approximately 76,000 km of roads, which include expressways, national highways, state highways, and major district roads. In addition, there are 200 km of bridges associated with these road types. Minor districts roads, rural roads, and private roads and bridges are not included in this assignment.

Road Segments

The procedure to define the replacement cost of the components of the road sector is based on the methodology proposed by Cardona et al. (2023). This procedure uses and processes the Global Roads Network dataset from OSM to eliminate wrong or incomplete records. The roads included are segmented into sections of a maximum of 300 m to increase the granularity of the model. The basic value of each segment is evaluated based on its length, using a nominal cost of \$1.09 million per km. The basic value of each segment is modified by the approximation to four main features: road type, number of lanes, pavement type, and slope. Each feature has a corresponding multiplication factor that modifies the basic value of the segment. The road type refers to the operational level of the road within the network of the country. It is an important modifier to account for variations in replacement cost depending on the overall importance of the road. 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 on a road segment serves as an indicator of the demand it accommodates. We use the factor proposed by Cardona et al. (2023), which is calculated as half the number of lanes in that segment. As such, a two-lane road represents the basic condition with a multiplication factor of 1. Roads with a higher number of lanes imply an amplification of the exposure value from the basic replacement cost. Additionally, the Pavement type also modifies the cost of the segment. It is evident that replacing a segment of the paved road would be costlier than replacing a segment of affirmed gravel. We apply the factors proposed by Cardona et al. (2023), categorizing three general categories: paved, affirmed, and loose. The associated 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 influences the value of a road segment. Replacing a road segment with similar characteristics in steep terrain is likely to be far costlier than replacing it in flat terrain. Furthermore, critical structures, such as retaining walls, are more commonly found in a steep terrain than in flat ones, where they may not be necessary. We use the slope factors Cardona et al. (2023) proposed, as 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

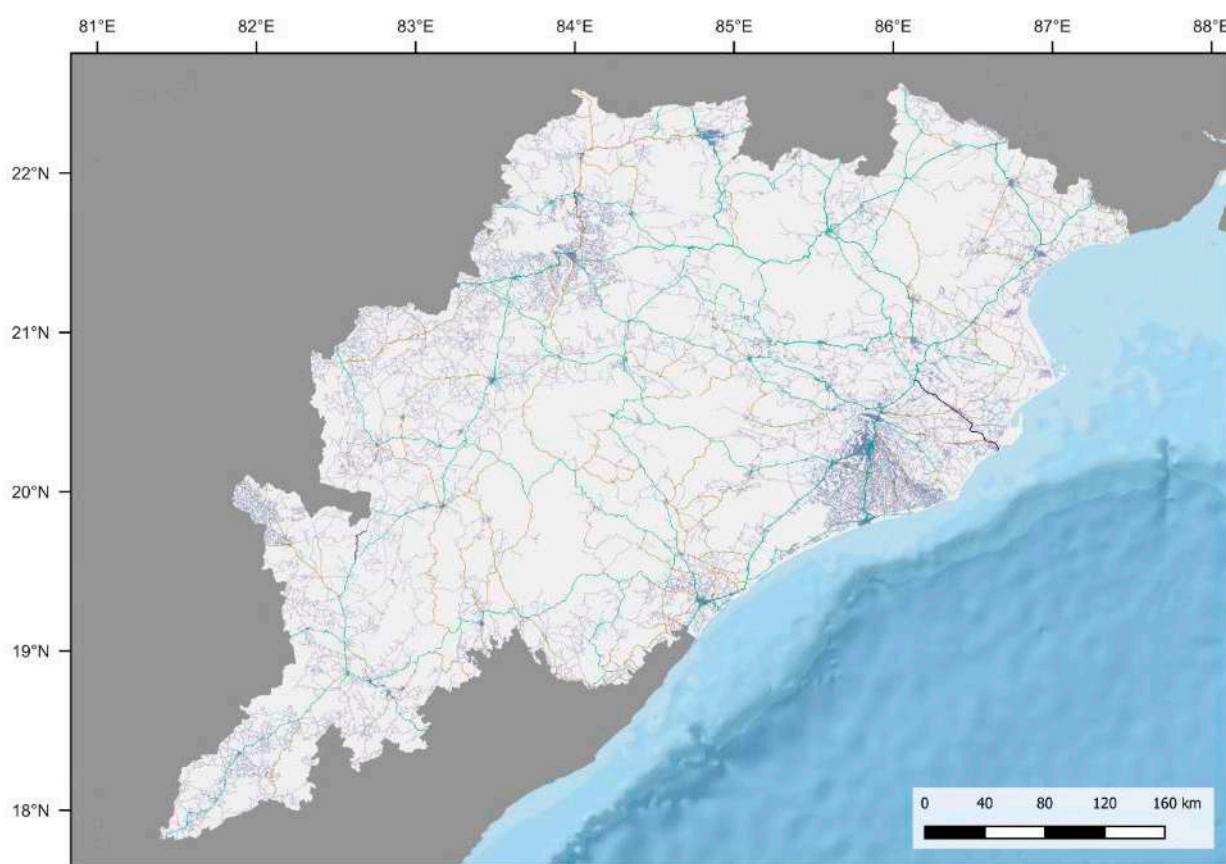
Bridges are infrastructure elements that are particularly difficult to categorize. It could be said, with a high degree of confidence, that there are as many types of bridges as there are bridges in the world. This variability complicates any attempt to classify them. Currently, the available data makes it impossible to create a comprehensive classification because we lack sufficient information to distinguish between structural differences in existing bridges. Key properties such as span, gauge, support type, number of pillars, type of abutments, foundation design, and board structure, among many others, remain unknown. The available data from the OSM dataset only allows for identifying bridge lengths. We

utilize this attribute to estimate replacement cost, using the cost indicator proposed by Cardona et al. (2023), which is \$9.84 million per km. Tunnels present similar difficulties to bridges in terms of classification and the lack of detailed information. Nonetheless, using the lengths of tunnels identified in the OSM dataset, the exposed value is approximated from the average price indicator proposed by Cardona et al. (2023), which is \$19.8 million per km.

Exposure Database

The resulting exposure model consists of geolocated vector entities that have attributes useful for risk evaluation. Key fields, such as the replacement cost and the archetype of each element, are included to effectively characterize the exposure. Figure 5.7 provides a general overview of the sector for Odisha.

Figure 5.7: Map of the Exposure Database for Road Sector in Odisha



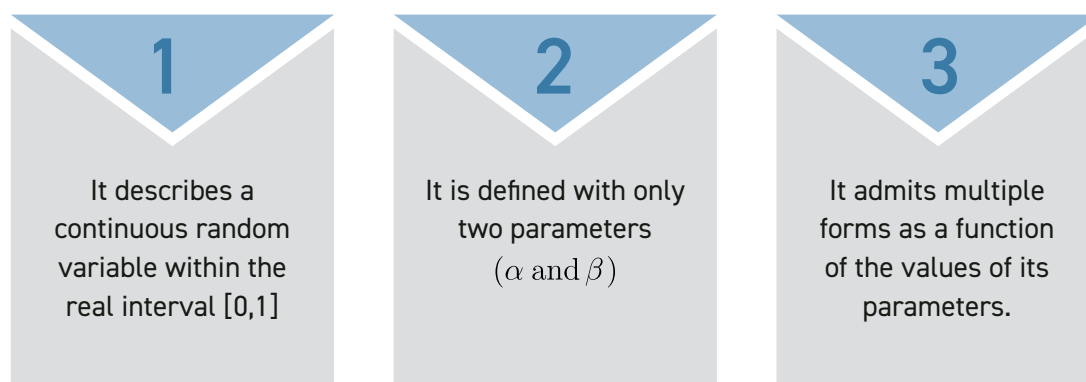
Vulnerability Models

The physical vulnerability of exposed elements can be represented mathematically using vulnerability functions. These functions effectively capture the complexity of the loss generation process when the exposed elements are subjected to the impact of a hazardous event. Additionally, vulnerability functions express losses in a probabilistic manner.

Probability Model for the Loss

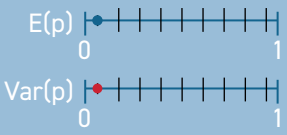
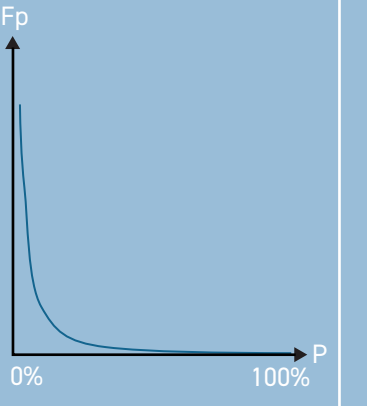
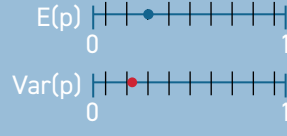
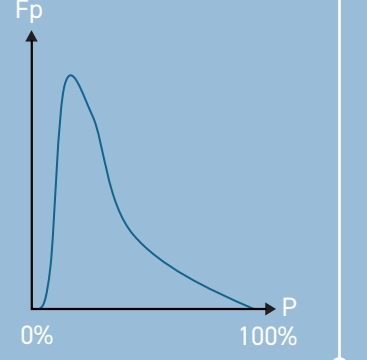
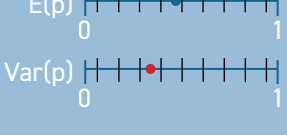
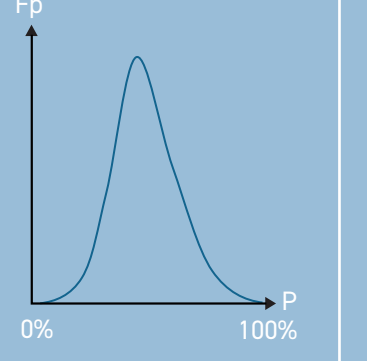
In catastrophic risk modelling, losses are treated as random variables. This allows the uncertainty inherent in the amounts of loss caused by any hazard to be directly considered in the calculations. Vulnerability is defined on an element-by-element basis within the exposure portfolio, meaning that the losses referred to pertain specifically to an individual exposed element. To generalize, loss can be defined as a variable in the range of 0 to 1, representing a scale from 0 to 100 percent of the exposed value of the element (e.g., the replacement value of a property or an infrastructure element). This means that, when discussing vulnerability, the term 'loss' consistently refers to a relative loss based on the degree of damage, which is expressed as a fraction of the exposed value.

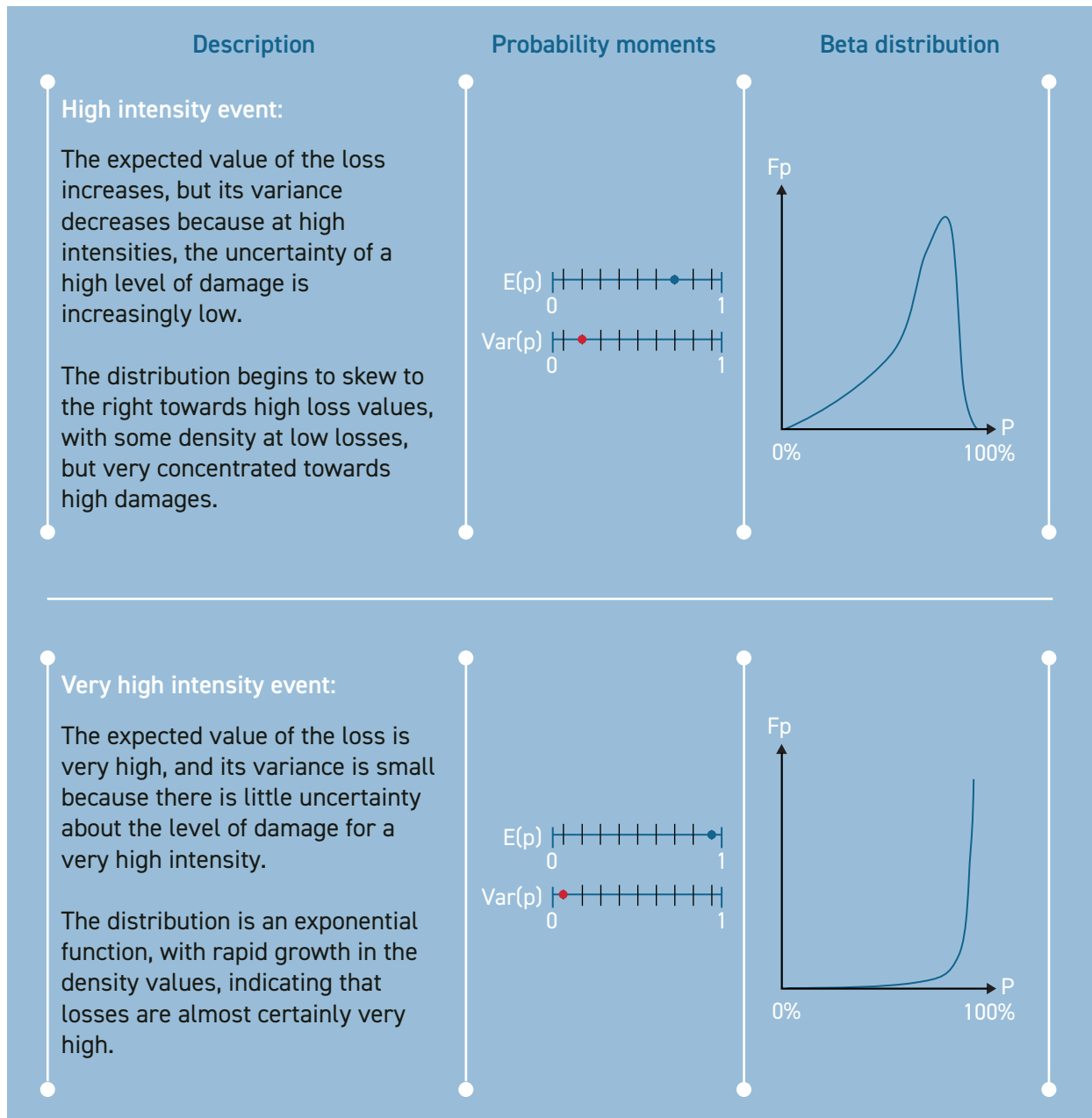
In general, there is insufficient information regarding the damage and losses caused by historical events to allow a probability model to adjust the loss based on statistical estimates. Therefore, the definition of a probability model that captures the randomness of loss is considered a reasonable and appropriate approach, although it is inherently somewhat arbitrary. The most widely used model is the Beta distribution, which was proposed by Anne Kiremidjian and other authors in developing the ATC-13 document and its commentary ATC-13-1 (ATC 1985; 2002). This work aimed to establish probability models for the damage resulting from earthquakes in California. Since then, the use of the Beta distribution as a probability model for loss has been widely adopted worldwide for all hazards and types of exposed elements, as it meets the following practical criteria:



As this is a two-parameter distribution, it requires two probability moments to characterize it. This implies that vulnerability models must account for at least two probability moments. Typically, vulnerability models are defined using the expected value and variance of the loss. The shape of the Beta distribution is influenced by the values of the probability moments estimated through the vulnerability model. As previously mentioned, the Beta distribution's ability to change its shape within its defined interval is a key reason for its wide use in catastrophe risk modelling. Table 5.9 illustrates the expected shapes of the Beta distribution based on various combinations of expected value and variance for losses. The table provides a general description of anticipated hazard events for different intensity levels, as well as details about the expected value and variance within the interval [0,1]. It also shows the expected shape of the Beta distribution for these parameters. In conclusion, the Beta distribution represents the expected shapes in which losses are likely to be distributed for events with different characteristics.

Table 5.9: Illustration of the Variation of the Beta Distribution in Response to Events of Different Intensity Levels

Description	Probability moments	Beta distribution
Very low intensity event: A low loss value is expected with a low dispersion. That is, if the intensity is very low, it is known that the loss will be low without much variability. 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 and centred more to the right, but it is 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.		

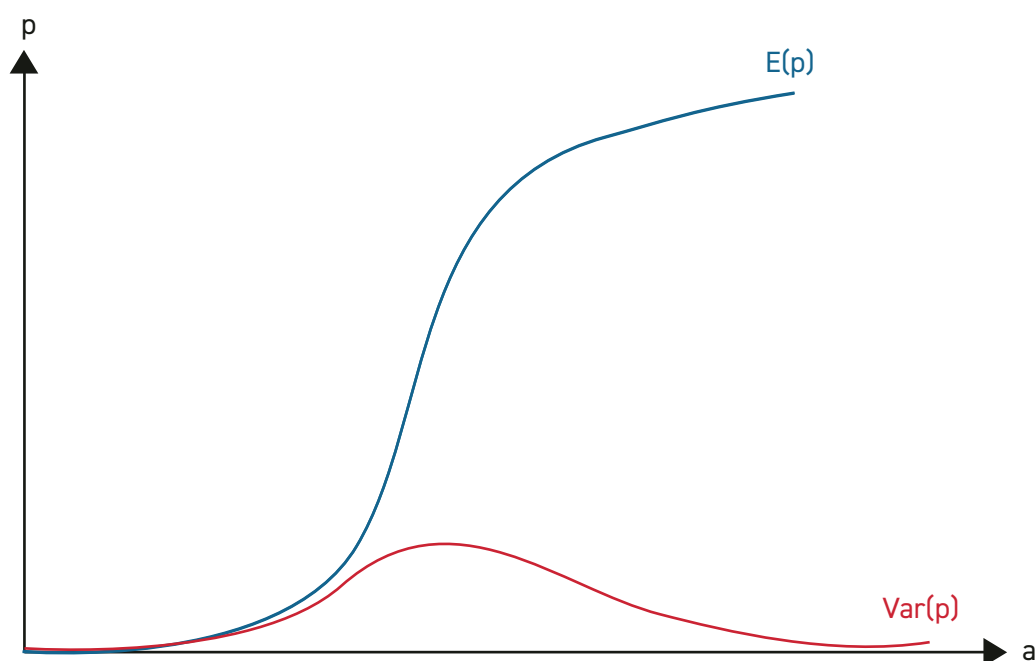


Vulnerability Functions

Vulnerability functions mathematically represent physical vulnerability and consist of two different functions. The first function describes how the expected value of the loss changes with the intensity of the phenomenon, while the second component explains how the variance of that loss varies. Vulnerability functions are the preferred vulnerability model for properties or infrastructure elements in catastrophe risk assessments because they effectively capture loss dynamics.

The expected value and variance functions follow specific patterns. In general, the expected value function must increase, while the variance function should initially increase and then decrease. This behaviour reflects the expected variability of the phenomenon as its intensity changes. Figure 5.8 shows a typical shape of vulnerability functions.

Figure 5.8: Illustration of a Vulnerability Function



Vulnerability functions are determined and established for various types of exposed elements, based on a categorization system. This implies that a single function can describe the behaviour of multiple exposed elements that belong to the same category. This approach is logical given the probabilistic nature of probability functions, as it models similar behaviours among exposed elements. The typification or categorization of exposed elements is established in the exposure model based on their construction or functional characteristics.

The vulnerability functions developed by Cardona et al. (2023) for infrastructure archetypes are used for this assignment. These functions are the same ones utilized in the GIRI model of CDRI. The GIRI library of archetype functions is currently the most comprehensive resource for infrastructure vulnerability models in catastrophe risk assessment. In this assignment, the vulnerability functions used for the risk assessment of Odisha are presented from Figures 5.9 to 5.12. As mentioned earlier, no vulnerability functions are applied for landslide hazard, based on the assumption that the occurrence of a landslide necessarily leads to the destruction of the infrastructure element. This assumption is particularly relevant for road infrastructure, which is the only type of infrastructure subjected to landslides in this assignment.

Energy Infrastructure

Figure 5.9: Earthquake Vulnerability Functions for the Infrastructure of the Energy Sector

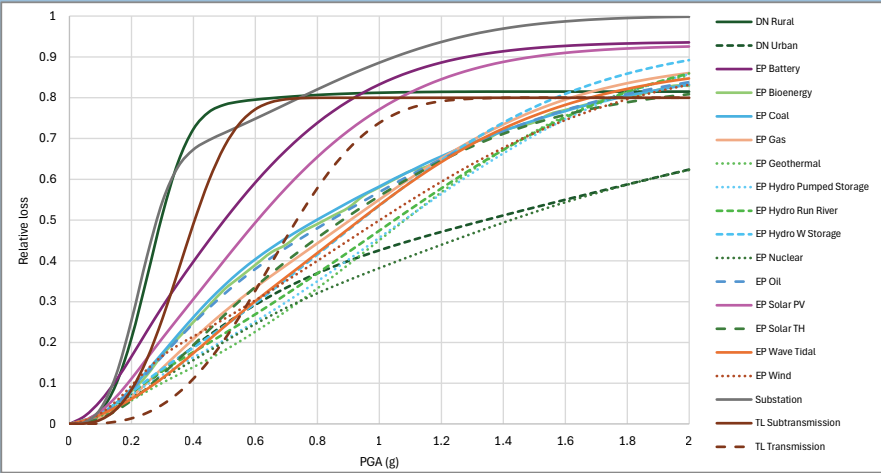


Figure 5.10: Flood Vulnerability Functions for the Infrastructure of the Energy Sector

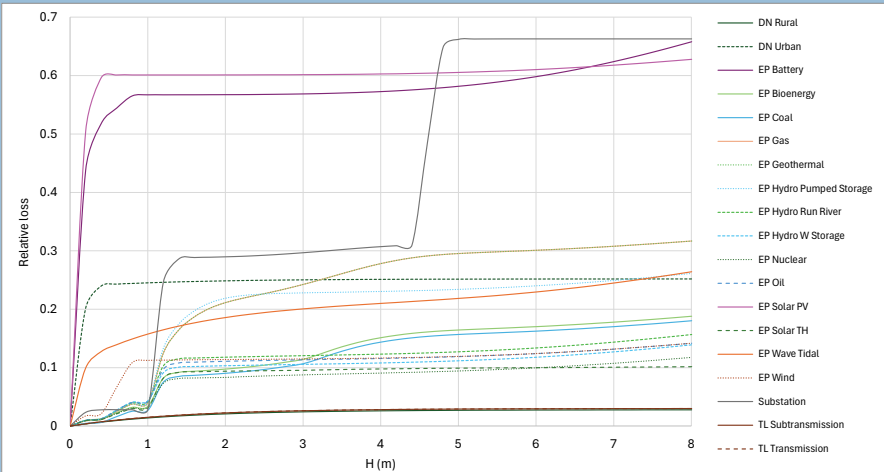


Figure 5.11: Storm Surge (Cyclone) Vulnerability Functions for the Infrastructure of the Energy Sector

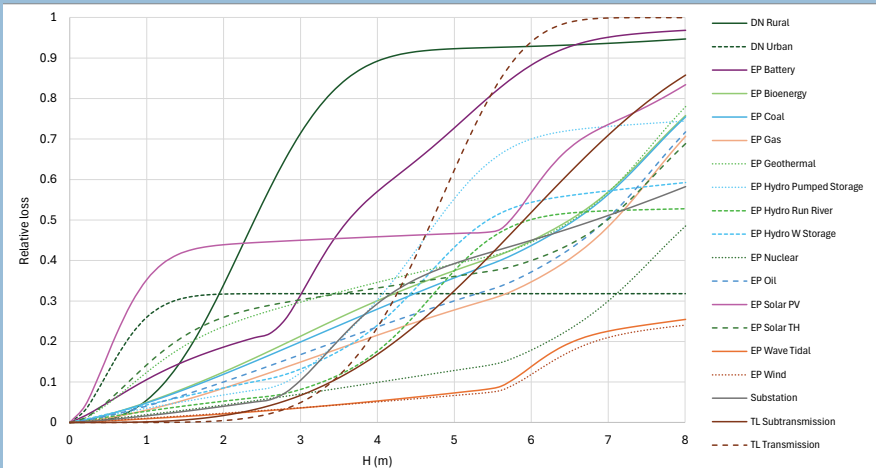
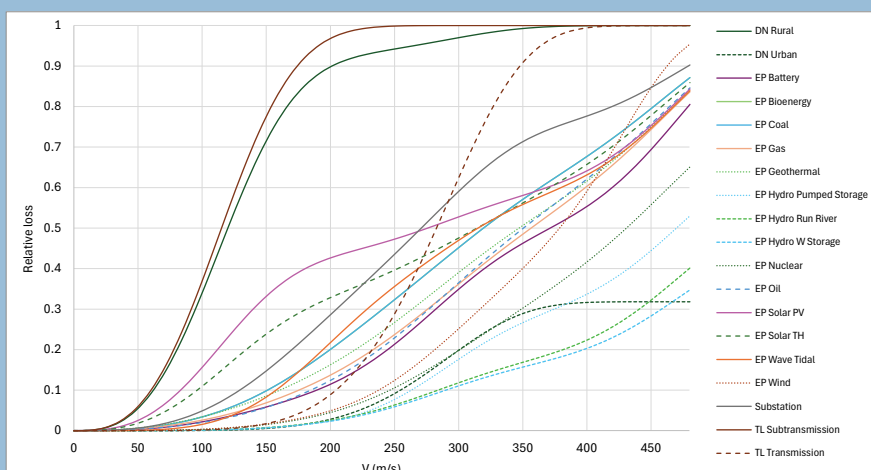


Figure 5.12: Wind (Cyclone) Vulnerability Functions for the Infrastructure of the Energy Sector



Road Infrastructure

Figure 5.13: Earthquake Vulnerability Functions for Infrastructure of the Road Sector

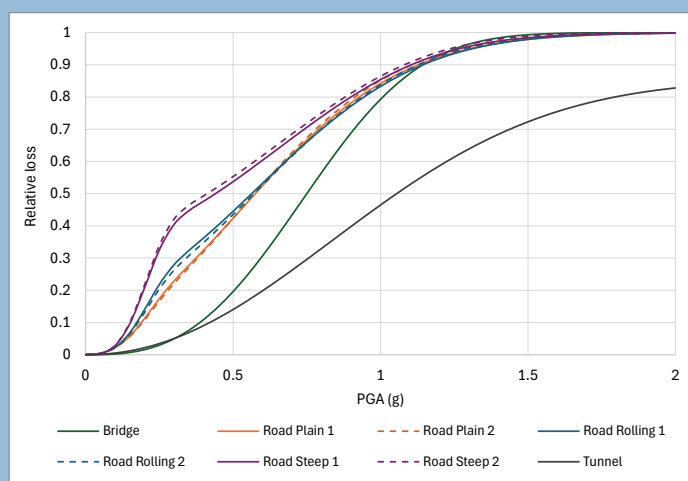
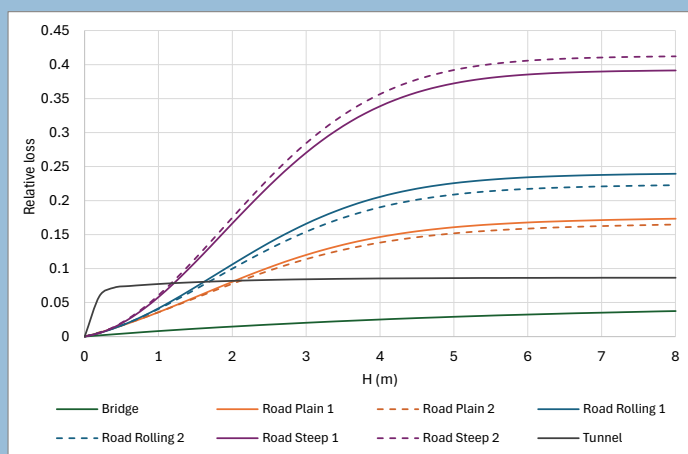
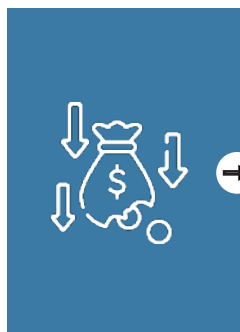


Figure 5.14: Flood Vulnerability Functions for Infrastructure of the Road Sector



Risk Assessment Results

Risk results are expressed using two standard metrics: the average annual loss (AAL) and the probable maximum loss (PML). These metrics are commonly utilized in catastrophe risk assessments and within the insurance industry. While these metrics are formally outlined in Product 1 of this consultancy, here the definitions are again provided for the reader's convenience.



Average Annual Loss:

The AAL is a crucial metric as it consolidates the impact of various hazard scenarios on vulnerable and exposed elements into a single value representing potential loss. It is considered the most reliable risk indicator due to its ability to resume the loss-time process in one number and its low sensitivity to uncertainty. The AAL represents the expected value of annual loss and indicates the annual value that should be paid to compensate for all future losses in the long term. In a simple insurance scheme, the AAL would equate to the annual pure premium.



Probable Maximum Loss:

This type of loss is infrequent, usually associated with long return periods. Rather than having a single PML value, there is a complete curve that illustrates the relationship between loss and return period. However, it is common practice to designate a specific PML value by selecting a fixed return period. There are no universally accepted standards to define what constitutes 'infrequent'. For example, in the insurance industry, the return periods used to define PML can range from 200 to 2,500 years.

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

The PML is presented as a function of loss in relation to the return period for each hazard and sector. The absolute PML values are included, while the relative PML values are presented to facilitate comparison among hazards. As for the AALs, absolute PMLs represent the calculated amount, while relative PMLs are normalized by the sector's exposed value. Given that PMLs are obtained from large quantiles within probability distributions, they cannot be disaggregated to present detailed maps. In this report, relative PMLs are always presented as per-hundred fractions with the symbol %.

Energy Infrastructure

Table 5.10 presents the AAL for Odisha's energy sector based on the hazards considered in this assessment, both in absolute and relative terms. It is important to note that the 56 highest losses are attributed to floods, particularly under the climate scenario SSP5- RCP8.5, which implies higher losses compared to other climate scenarios, though the variations are not significant. In the case of tropical cyclones, the current climate results in higher losses than the projected future altered climate, once more highlighting the nonlinear relationship between greenhouse gas (GHG) emissions and disaster risk. The lowest AAL is associated with earthquakes, due to the low seismic hazard in Odisha.

Table 5.10: Absolute and Relative Average Annual Loss for the Energy Sector Infrastructure

Hazard	Average annual Loss	
	\$	%
Earthquake	3,505,000	0.07
Flood	119,378,000	2.50
Flood (RCP2.6)	118,188,000	2.48
Flood (RCP8.5)	134,236,000	2.82
Tropical cyclone	94,779,000	1.99
Tropical cyclone	51,944,000	1.09



The distribution of the relative AAL among subsectors is summarized as follows. In the case of earthquake hazard [see Figure 5.15(a)], the generation and distribution subsectors exhibit the highest relative AAL. This is logical, as such a hazard can lead to correlated losses across multiple locations during a single event. Nonetheless, it is important to note that the AAL values for all earthquakes are quite low. In the case of floods [see Figure 5.15(b)], the distribution subsector incurs the highest AAL, followed by the generation subsector. The AAL for the transmission sector remains low, which is expected due to the predominant nature of transmission lines being elevated. Finally, the assessment of AALs for tropical cyclones [illustrated in Figure 5.15(c)] shows that the generation subsector experiences a significantly higher impact, while the transmission and distribution subsectors have low AAL values. This difference is largely due to the greater sensitivity of power plants and facilities to wind, as they are composed of elements that are more susceptible to wind damage. In contrast, transmission or distribution infrastructure, like transmission towers and substations, tends to be less sensitive to wind. Furthermore, the disaggregated AALs reflect a reduction in risk for Odisha's energy sector when considering a future climate characterized by high emissions.

Figure 5.15: Relative AAL from (A) Earthquake, (B) Flood, and (C) Tropical Cyclones for the Energy Infrastructure Portfolios



The AAL for each subsector is calculated by aggregating the individual losses for each exposed element. Each element in the exposure portfolio has unique characteristics, including location, price, and vulnerability, which contribute to a distinct risk evaluation for each one. The AAL is further disaggregated by element to illustrate these differences and the uniqueness of each element within the risk landscape. The maps presented in Figures 5.16 to 5.21 effectively illustrate the variation in relative AAL among the exposed elements in the energy sector, taking into account all the hazards and climate scenarios considered.

Figure 5.16: Map of Relative AAL from Earthquakes for the Energy Portfolios

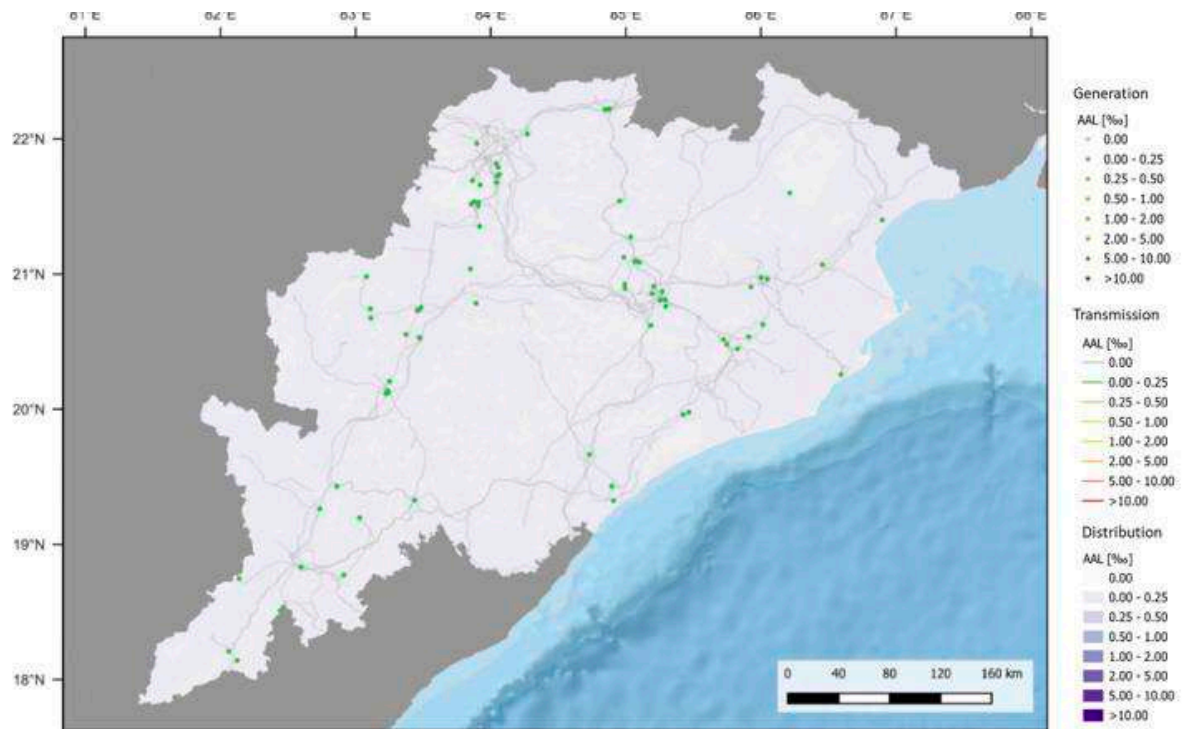


Figure 5.17: Map of Relative AAL from Earthquakes for the Energy Portfolios

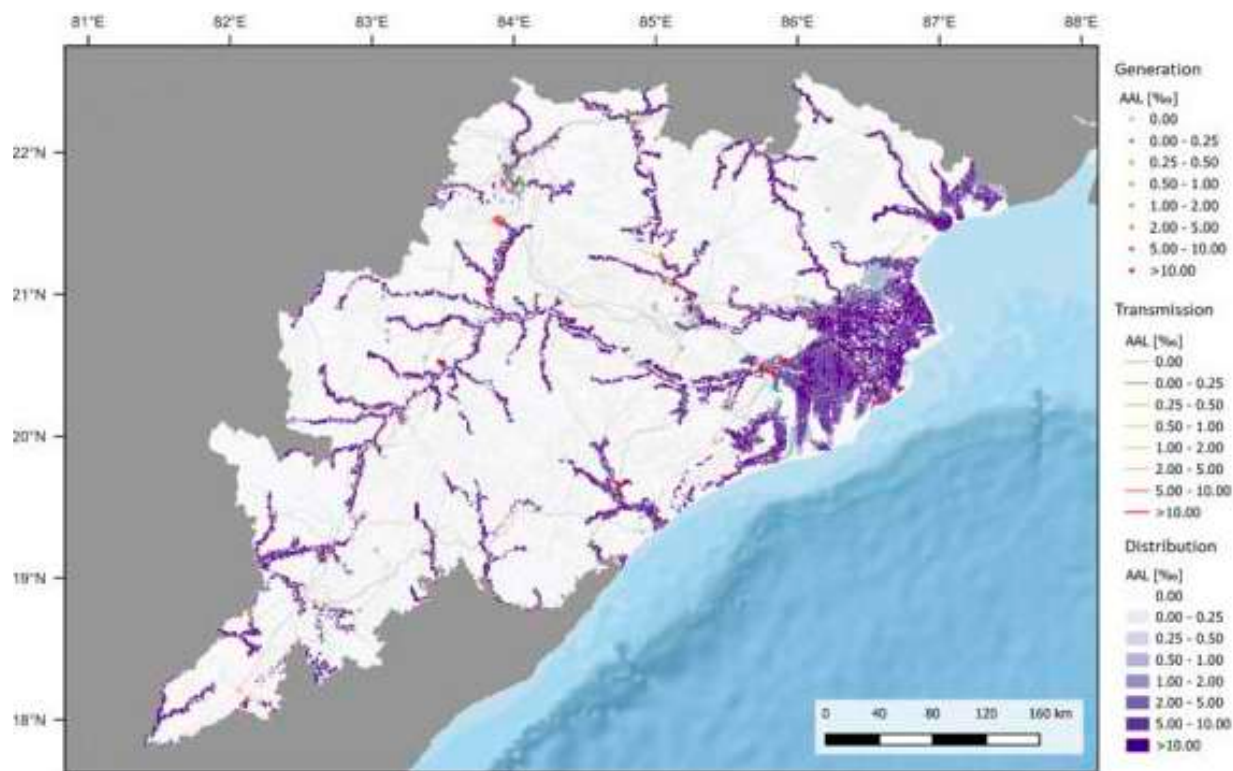


Figure 5.18: Map of Relative AAL from Floods (SSP1-RCP2.6) for the Energy Portfolios

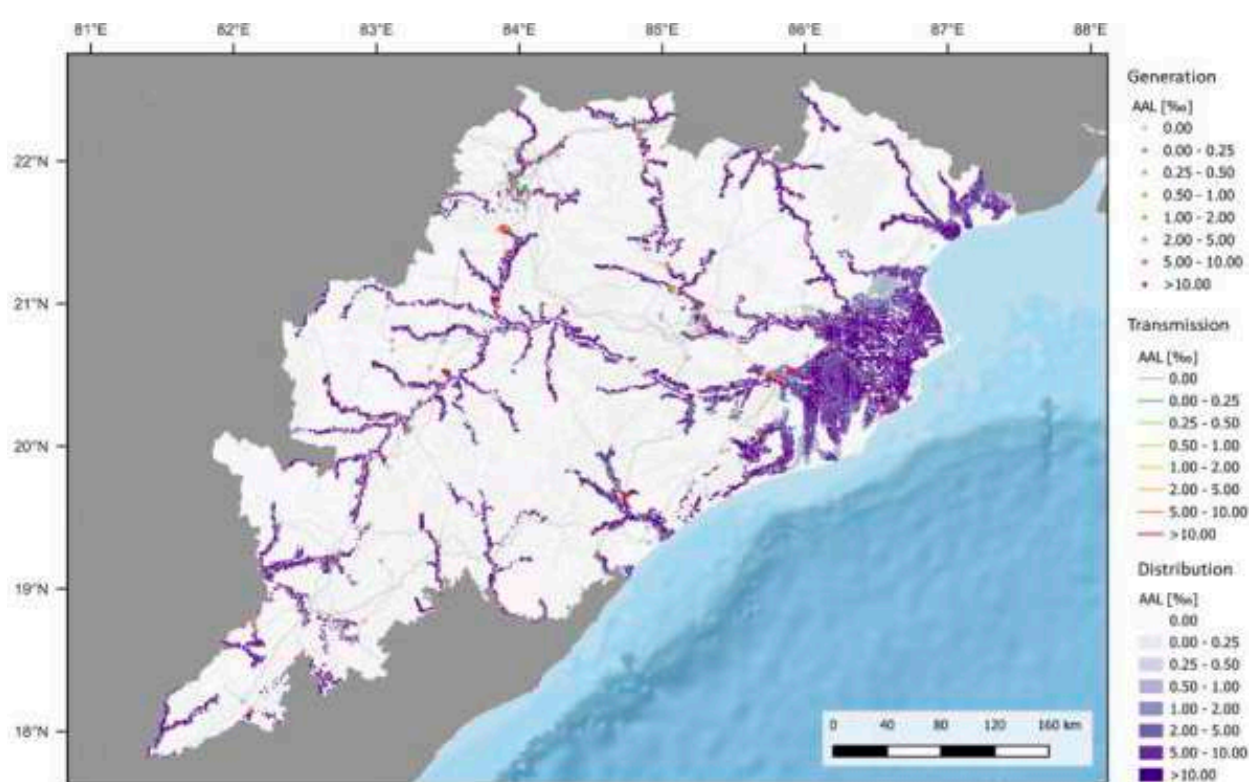


Figure 5.19: Map of Relative AAL from Floods (Ssp5-Rcp8.5) for the Energy Portfolios

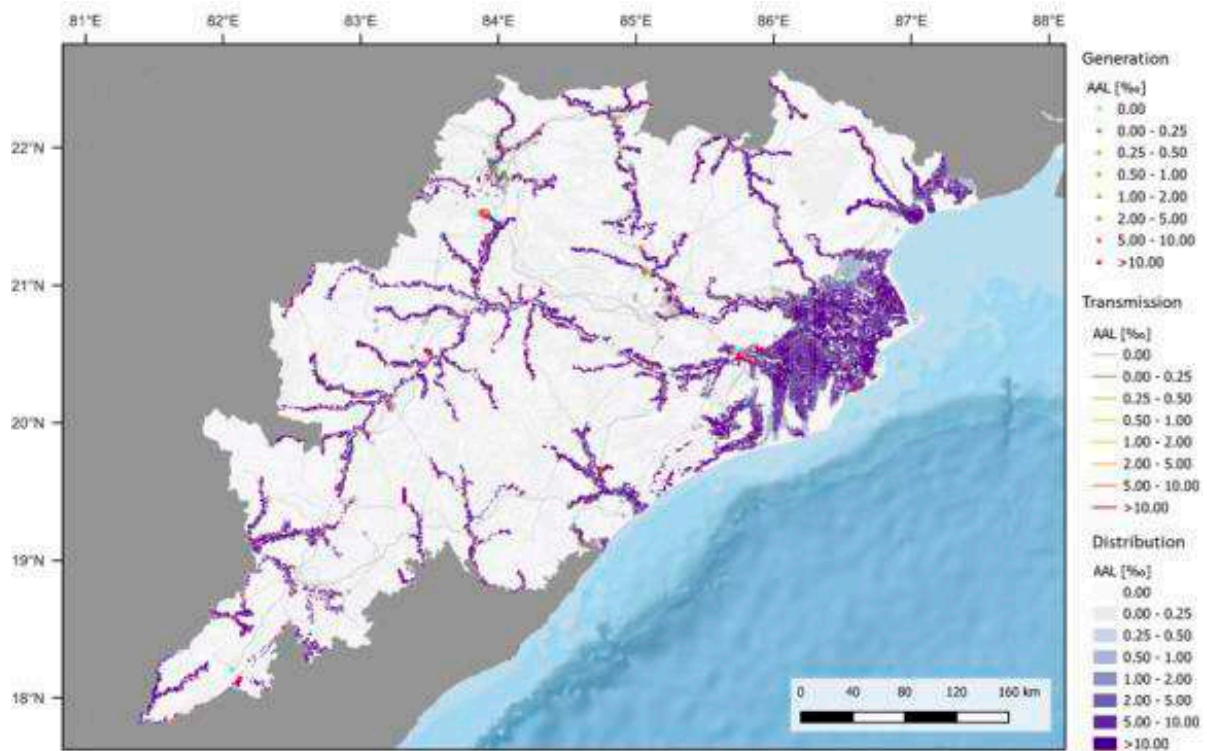


Figure 5.20: Map Of Relative AAL from Tropical Cyclones for the Energy Portfolios

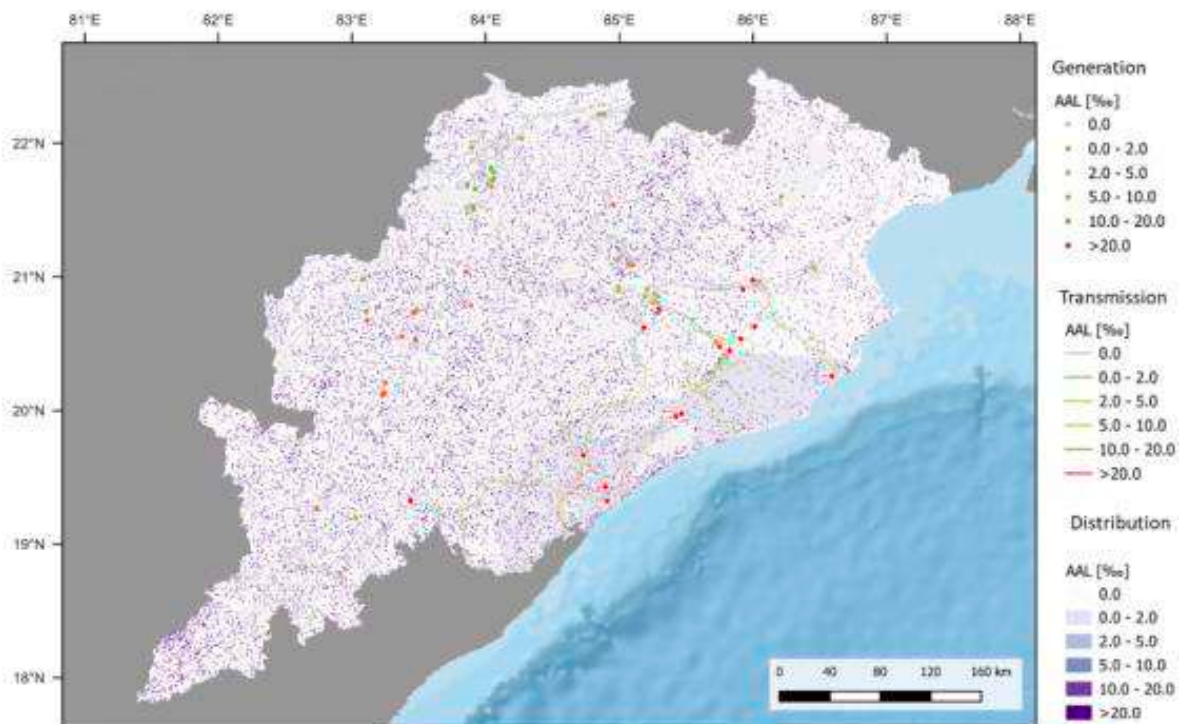


Figure 5.21: Map of Relative AAL from Tropical Cyclones (SSP5-RCP8.5) for the Energy Portfolios

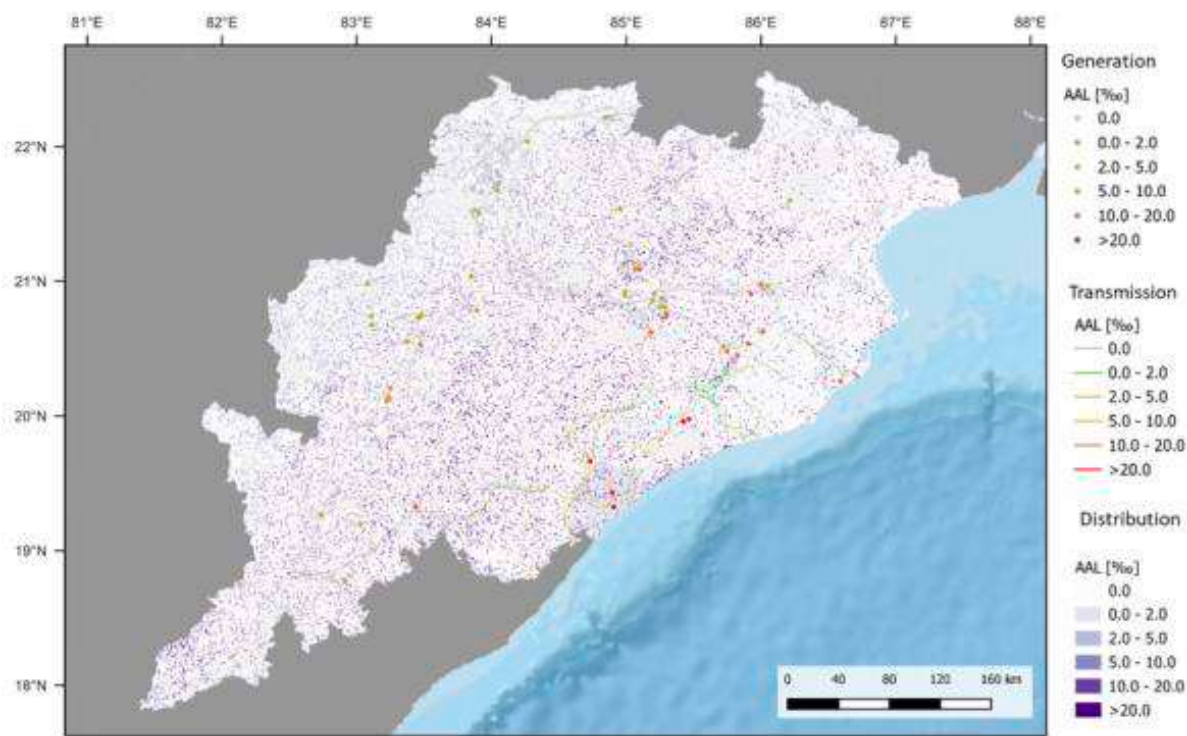
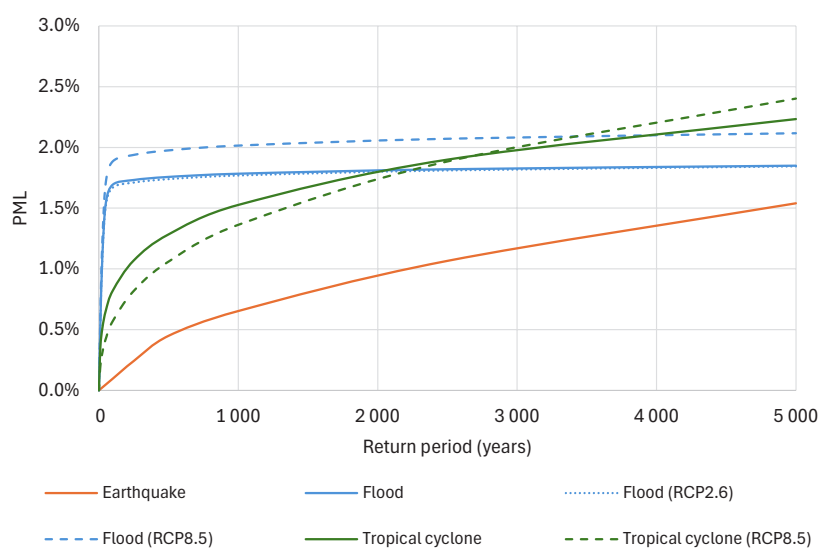


Table 5.11 presents the PML values for the energy sector of Odisha, categorized by hazard type and selected return periods. Generally, PML values are always higher in magnitude than AALs due to their definitions and calculation methods. These PML values are depicted in relative terms in Figure 5.22, shown as PML curves that illustrate the metric's variation with different return periods. As expected, the risk associated with tropical cyclones predominates in the long return period segment of the curve for Odisha. Flood risks are more significant for return periods shorter than 2,000 years. It is notable that the PML function for earthquake and tropical cyclones shows a steep increase, while the PML curve for floods remains relatively flat. This difference reflects the frequency of hazard events.

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

Return period (years)	Eartquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Tropical cyclone	Tropical cyclone (RCP8.5)
10	\$4,610,000	\$258,401,000	\$255,215,000	\$289,073,000	\$167,859,000	\$94,017,000
25	\$11,526,000	\$533,267,000	\$525,004,000	\$592,424,000	\$245,511,000	\$149,046,000
50	\$23,051,000	\$738,567,000	\$726,691,000	\$819,516,000	\$314,253,000	\$203,799,000
100	\$46,103,000	\$808,417,000	\$796,228,000	\$899,257,000	\$391,994,000	\$272,503,000
250	\$115,256,000	\$826,302,000	\$815,663,000	\$924,128,000	\$509,968,000	\$390,378,000
500	\$214,155,000	\$838,351,000	\$829,104,000	\$941,885,000	\$612,284,000	\$505,645,000
1,000	\$311,471,000	\$850,948,000	\$843,246,000	\$960,755,000	\$727,816,000	\$649,847,000
2,500	\$508,423,000	\$868,466,000	\$863,066,000	\$987,507,000	\$905,533,000	\$898,661,000
5,000	\$734,615,000	\$882,401,000	\$878,953,000	\$1,009,197,000	\$1,064,759,000	\$1,145,589,000

Figure 5.22: PML Curve for the Energy Sector Infrastructure



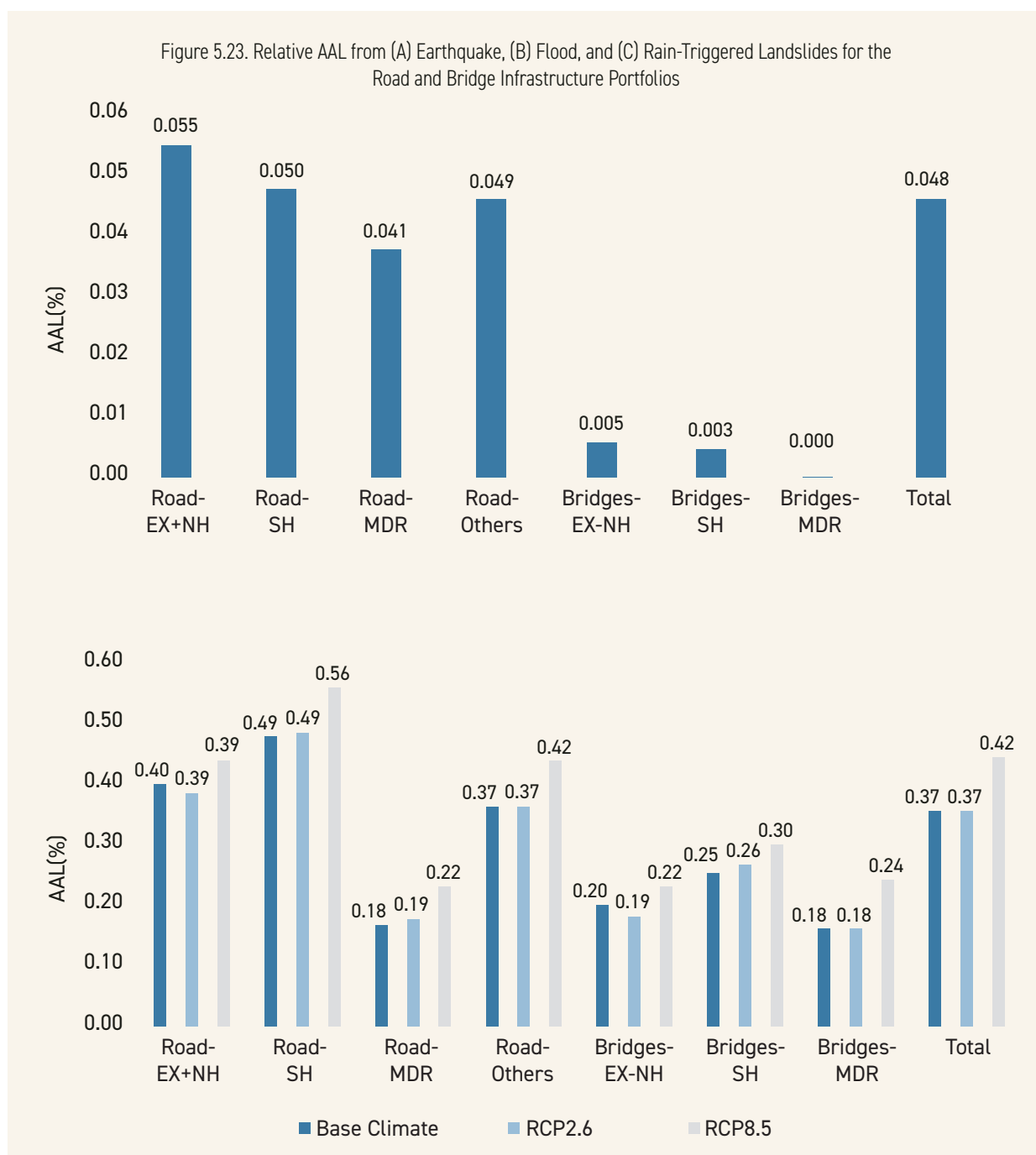
Roads Infrastructure

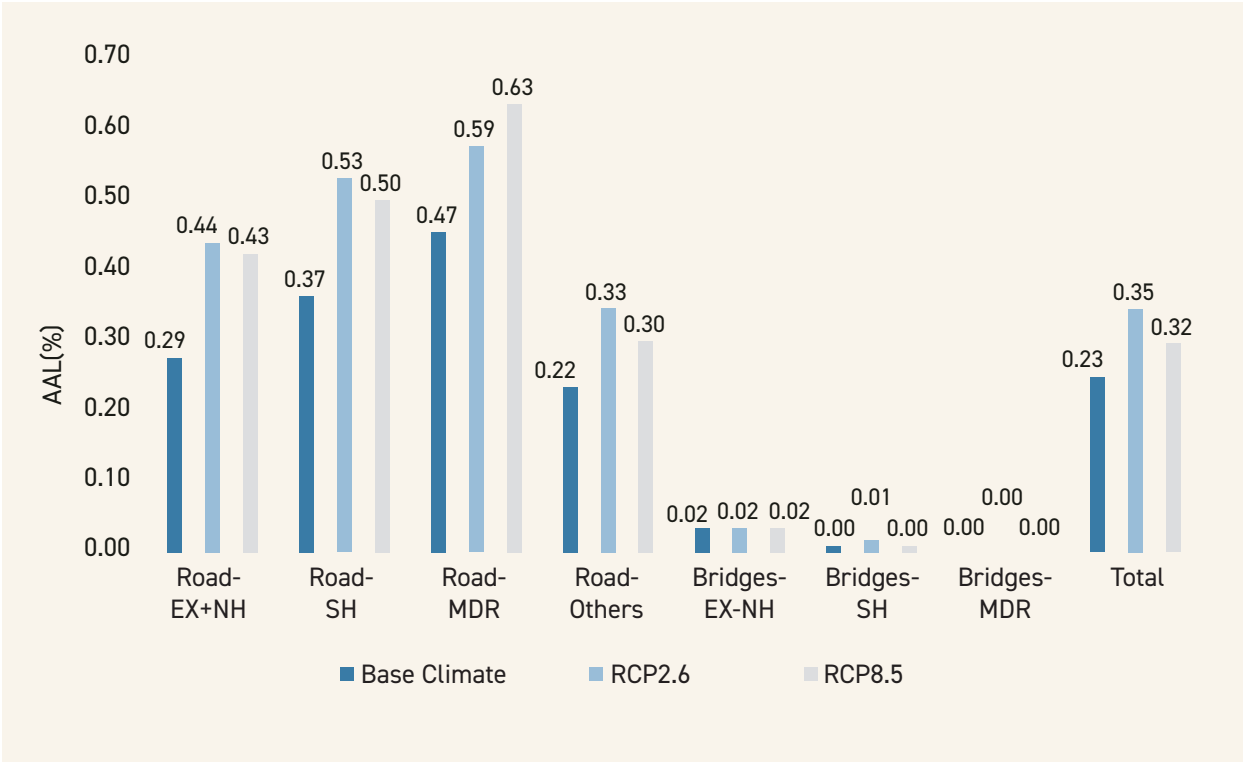
Table 5.12 presents the AAL for Odisha's Road sector, taking into account the various hazards considered in this assessment, both absolute and relative. Note that the highest losses in this case are attributed to floods and rain-triggered landslides. In contrast, earthquakes contribute the least to the AAL, and earthquake-triggered landslides do not contribute at all. This difference is primarily due to the frequency of these events, which is rather large for hydrometeorological hazards like floods and rain-triggered landslides and low for earthquakes and the landslides they induce, especially in low seismicity regions like Odisha.

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

Hazard	Average annual Loss	
	\$	%
Earthquake	\$2,565,000	0.05
Landslide - Earthquake	\$3,000	0.0001
Flood	\$19,868,000	0.37
Flood (RCP2.6)	\$19,807,000	0.37
Flood (RCP8.5)	\$22,588,000	0.42
Landslide - Rain	\$12,306,000	0.23
Landslide - Rain (RCP2.6)	\$18,637,000	0.35
Landslide - Rain (RCP8.5)	\$17,159,000	0.32

The relative AAL among subsectors is distributed as shown next. In the case of earthquake hazard (see Figure 5.23), all AAL values are similar and very low. For floods, the AALs are again distributed evenly among sectors, with lower values for bridges. Note that there is no significant variation in AALs among different climates, although the SSP5-RCP8.5 scenario exhibits a consistent increase among sectors. This contrasts with the AALs for rain-triggered landslides, where the higher values are for the major district roads, probably due to the higher dispersion of this portfolio. Additionally, it is important to note that AAL tends to be higher under the climate scenario SSP1-RCP2.6, showing the high non-linearity between GHG emissions and disaster risk.





The AAL of each road segment in the model is presented in Figures 5.24 to 5.30, categorized by hazard. These maps illustrate the variation in relative AAL among the various exposed elements of the road network, despite the vast size of the country.

Figure 5.24: Map Of Relative AAL from Earthquakes for the Road Portfolios

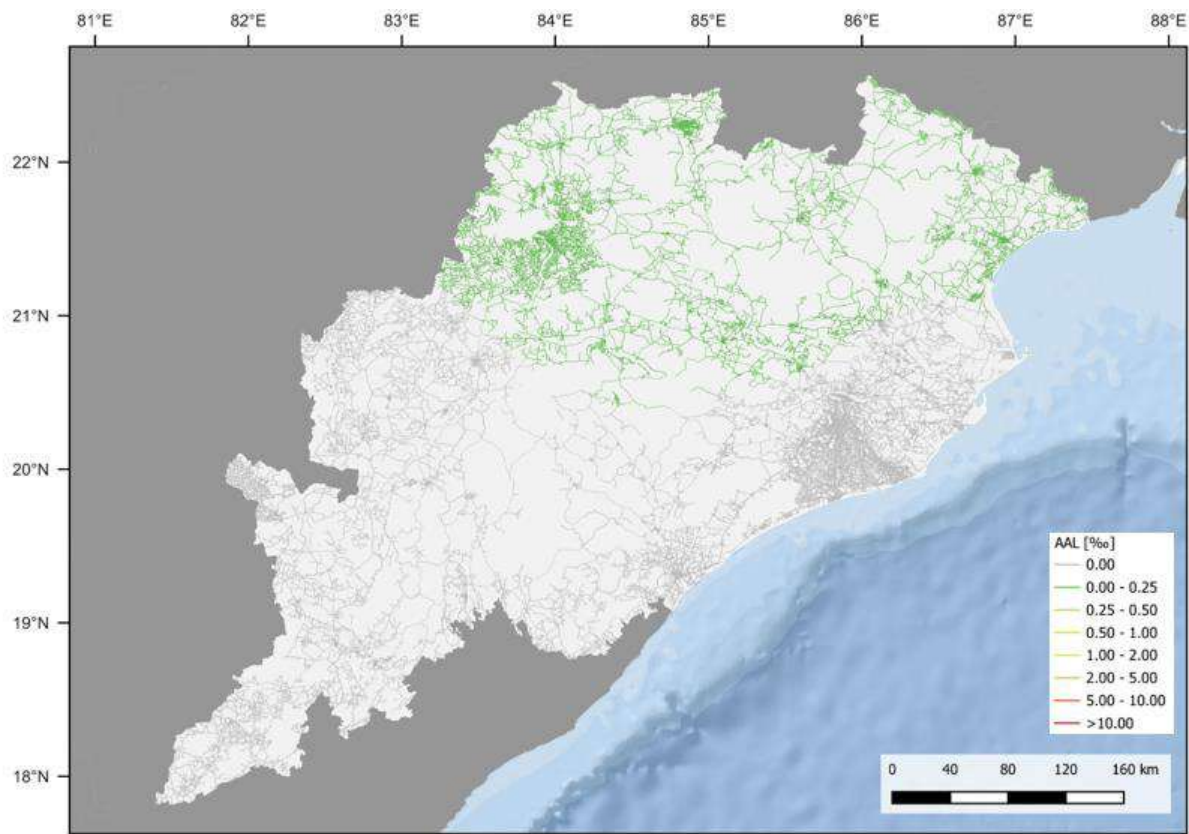


Figure 5.25: Map of Relative AAL from Floods for the Road Portfolios

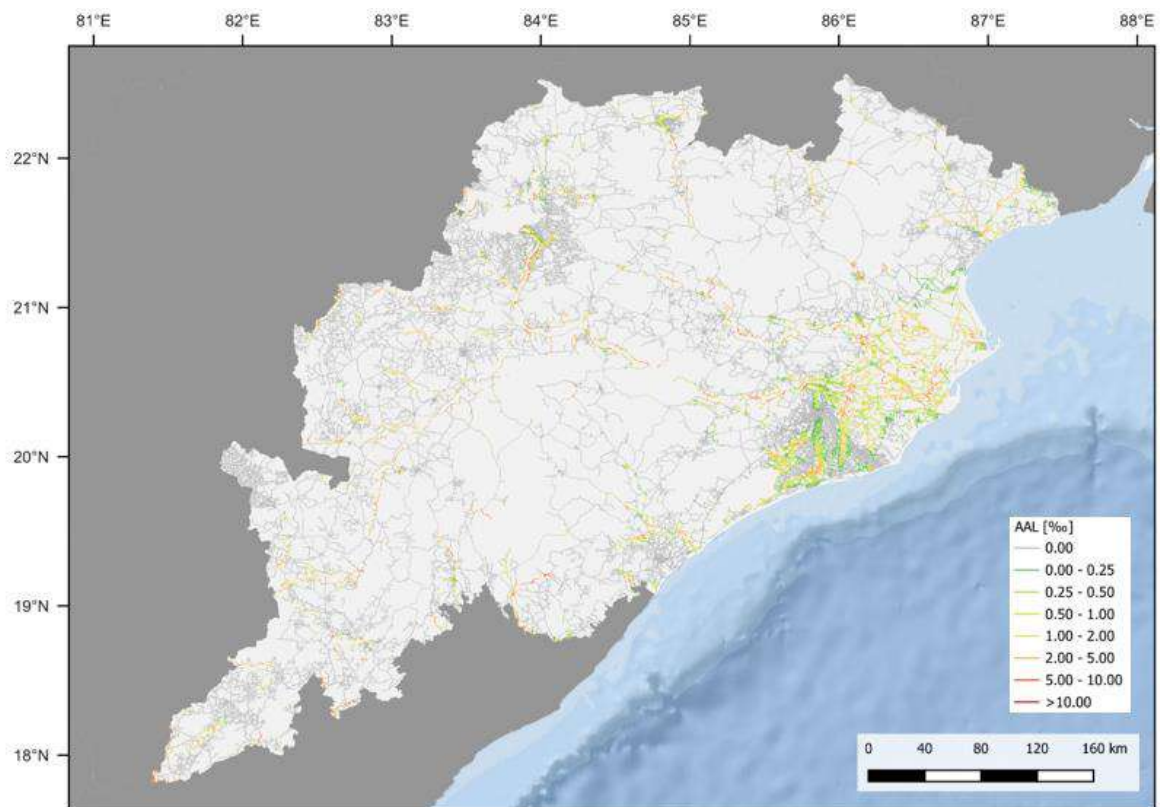


Figure 5.26: Map of Relative AAL From Floods (SSP1-RCP2.6) for the Road Portfolios

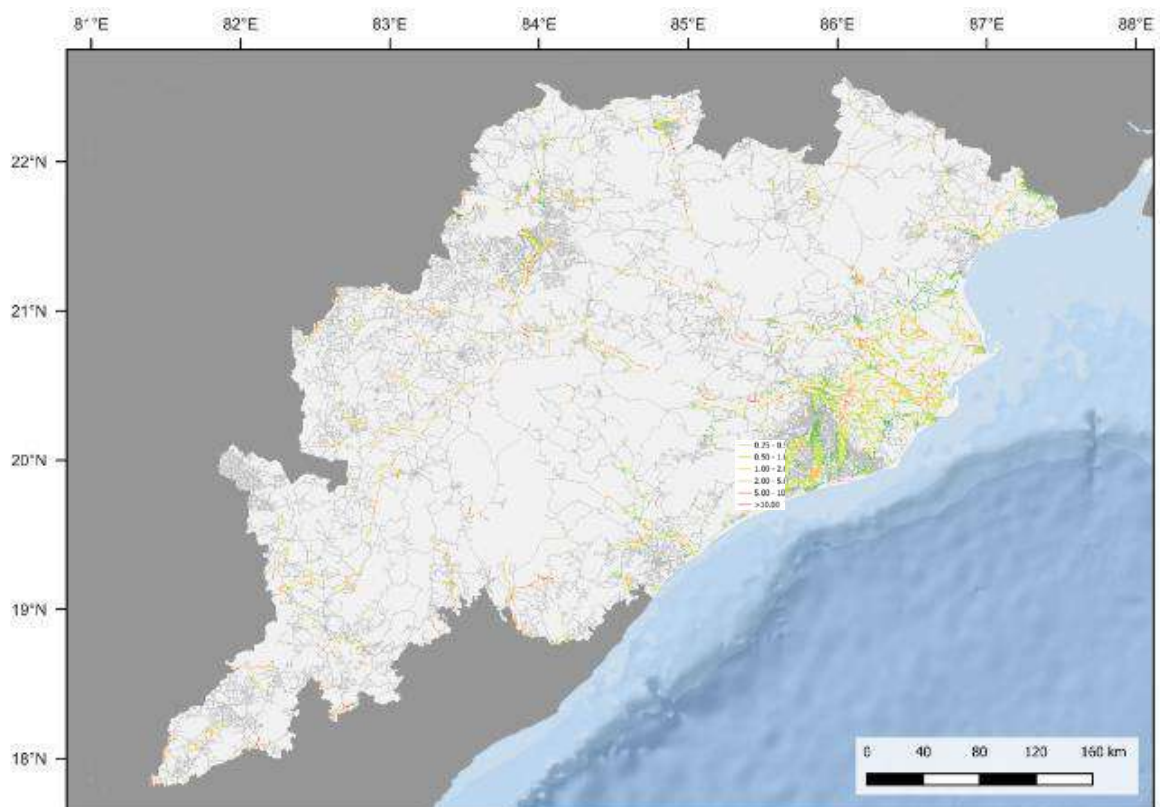


Figure 5.27: Map Of Relative AAL from Floods (SSP5-RCP8.5) for the Road Portfolios

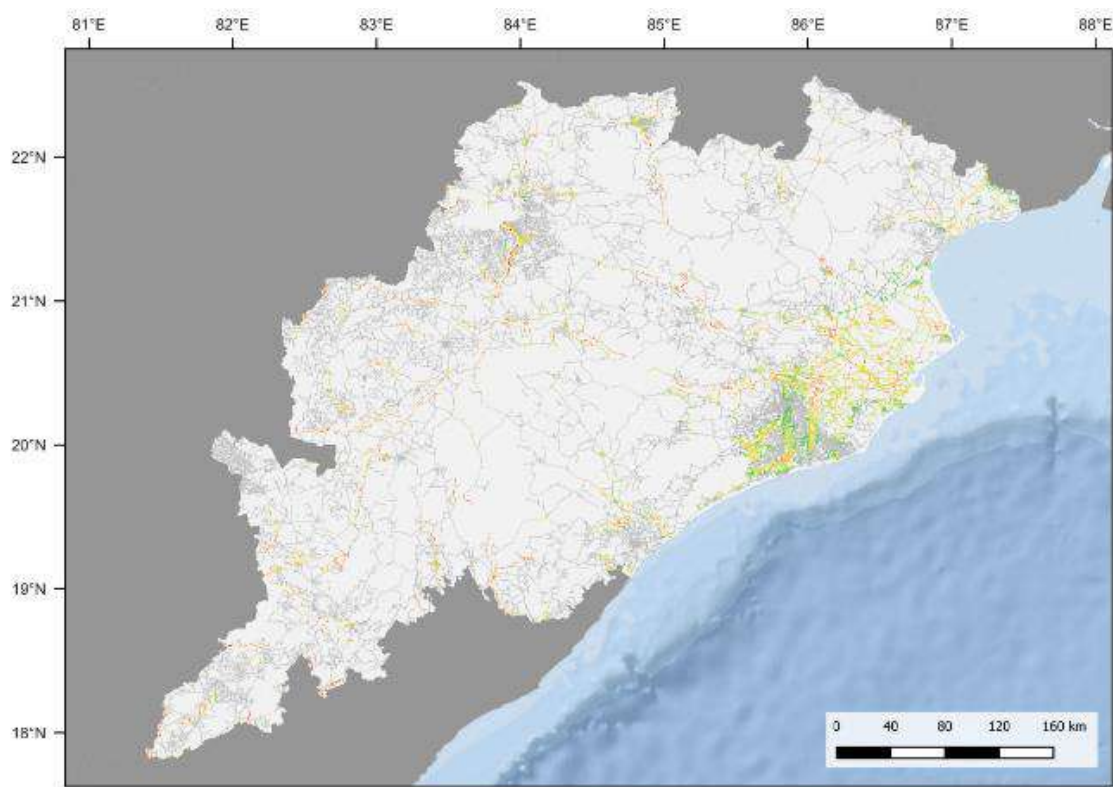


Figure 5.28: Map of Relative AAL from Rain-Triggered Landslides for the Road Portfolios

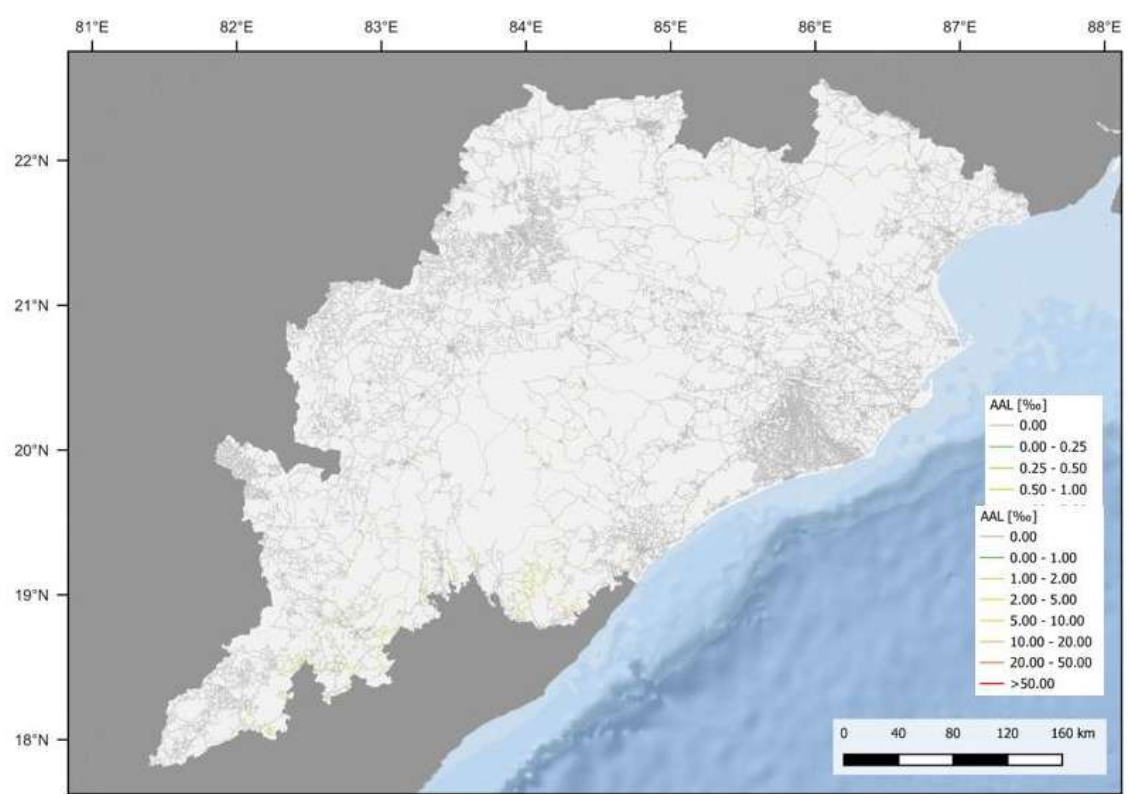


Figure 5.29: Map of Relative AAL from Rain-Triggered Landslides (SSP1-RCP2.6) for the Road Portfolios

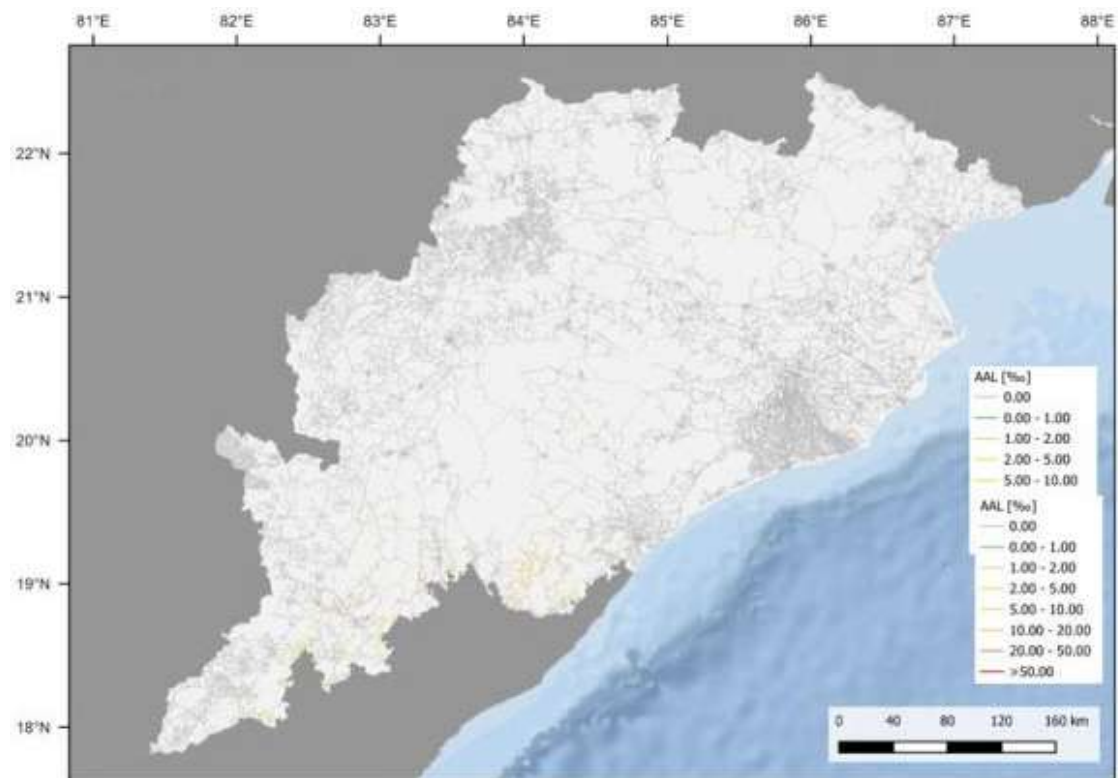


Figure 5.30: Map of Relative AAL from Rain-Triggered Landslides (SSP5-RCP8.5) for the Road Portfolios



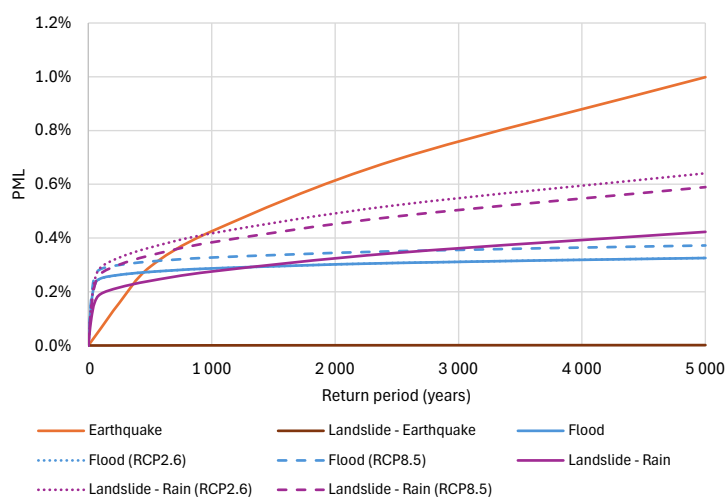
Table 5.13 presents the PML values for the road sector of Odisha, categorized by hazard, and for some selected return periods. As mentioned, PMLs consistently exceed AALs in magnitude than AALs across all calculated return periods.

Table 5.13: PML for the Roads and Bridges Infrastructure (Values In Thousand \$)

Return period (years)	Earthquake	Landslide - Earthquake	Flood	Flood (RCP2.6)	Flood (RCP8.5)	Landslide Rain	Landslide - Rain (RCP2.6)	Landslide - Rain (RCP8.5)
10	\$3,376	\$4	\$42,562	\$42,436	\$48,399	\$25,589	\$38,753	\$35,681
25	\$8,441	\$11	\$86,679	\$86,433	\$98,599	\$55,630	\$84,248	\$77,568
50	\$16,882	\$22	\$120,169	\$119,837	\$136,720	\$84,830	\$128,469	\$118,283
100	\$33,764	\$43	\$133,432	\$133,077	\$151,843	\$102,512	\$155,248	\$142,939
250	\$84,410	\$108	\$140,513	\$140,166	\$159,972	\$115,347	\$174,686	\$160,835
500	\$156,493	\$203	\$146,499	\$146,168	\$166,867	\$128,547	\$194,678	\$179,242
1000	\$227,220	\$298	\$153,443	\$153,138	\$174,884	\$147,228	\$222,969	\$205,290
2500	\$370,046	\$494	\$164,352	\$164,097	\$187,509	\$184,308	\$279,125	\$256,993
5000	\$533,730	\$722	\$174,140	\$173,942	\$198,867	\$226,104	\$342,422	\$315,271

Figure 5.31 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 beyond a 500-year return period. This indicates that earthquakes have a significantly greater impact on the potential risk associated with large or catastrophic events. As mentioned earlier, the rate of the earthquake PML function is much steeper compared to the PML curve for rain-triggered landslides and the relatively flat curve for floods. In any case, all the PML values for Odisha are quite low.

Figure 5.31: PML Curve for the Road and Bridge Infrastructure



It is important to note that floods result in higher AAL to infrastructure in Odisha. Based on data from the previous tables, Table 5.14 shows the combined absolute AAL in selected sectors associated with the hazards considered.

Table 5.14: Absolute AAL

Hazard	AAL (\$ '000)	
	Energy	Roads and Bridges
Earthquake	3,505	2,565
Flood	119,378	19,868
Flood (RCP2.6)	118,188	19,807
Flood (RCP8.5)	134,236	22,588
Tropical cyclone	94,779	-
Tropical cyclone - Rain (RCP8.5)	51,944	-
Landslide – Earthquake	-	3,000
Landslide – Rain	-	12,306
Landslide - Rain (RCP2.6)	-	18,637
Landslide - Rain (RCP8.5)	-	17,159

PML for Energy Infrastructure

Floods with return periods ranging from 10 to 2,500 years are likely to cause the highest PML to the energy infrastructure sector. Only tropical cyclones with a return period of 5,000 years are expected to result in a greater PML.

PML for Roads and Bridges

For roads and bridges, the highest PML is due to rain-induced landslides and floods, especially those with return periods exceeding 50 years.

Chapter 6

Post-Disaster Funding Gap Assessment



Post-Disaster Funding Gap Assessment

Post-Disaster Funding Gap Assessment is the systematic process to determine the available financial resources for recovery and reconstruction and estimate the additional funding requirements. Undertaking timely funding gap assessment is critical in ensuring that affected sectors receive the necessary resources to rebuild and recover effectively and efficiently. Since it is a multi-faceted process, it requires various perspectives to ensure fiscal resilience. There are advantages in undertaking funding gap assessment *ex ante*. Funding gap assessments can:

1

Provide decision-makers with the essential data to make informed choices about where to allocate resources at different stages of recovery. By identifying funding gaps and understanding the financial requirements for various recovery initiatives, stakeholders can systematically prioritize projects and redirect funds to address new or escalating needs for efficiency and impact

2

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

3

Help to inform the choice and design of a particular disaster risk financing (DRF) intervention, as well as the choice and design of underlying triggers.

4

Can be used to advocate additional funding from governments, international organizations, donors, and the private sector. Resource mobilization is a pivotal component of ensuring efficient disaster recovery, and funding gap assessments play a crucial role in this process. It also guides stakeholders in identifying which resources are most critical and how they can be leveraged strategically to support recovery initiatives.

5

Enhance transparency and accountability in the recovery process. Stakeholders can monitor the allocation and utilization of funds, reducing the risk of corruption and mismanagement

6

Help ensure no unnecessary bottlenecks in funding availability, enabling a more rapid and efficient response to recovery needs without delay.

7

Enable international donors and humanitarian organizations to target their aid and donations effectively. They can channel their resources to areas with the greatest need, maximizing the impact of their assistance.

Disaster Impacts

A look at the historical occurrence of disasters in Odisha indicates that the SDRF, as the immediate source of funds for post-disaster expenditures in Odisha, is not sufficient. The amount of reserved funds in the SDRF will require augmentation from the NDRF and other sources to meet post-disaster needs annually. Aggregating the effects of cyclones, floods, and drought since 2013, the table below shows the total losses in Odisha. The estimated economic loss due to natural disasters from 2014 to 2021 is around 3.82 percent of GSDP (as per 2021-22 GSDP). Economic losses include crop loss, infrastructure damage, livestock loss, private properties.

Table 6.1: Disasters and Estimated Economic Loss Since 2013 (in US\$ million)

Year	Disaster	Total Losses
2013	Cyclone Phailin and flood	2642,62
2014	Cyclone Hudhud	823,46
2015	Drought	374,66
2016	Flood	4,67
2017	Flood	33,31
2018	Cyclone Titli, flood and drought	663,24
2019	Cyclones Fani and Bulbul	1385,72
2020	Cyclone Amphan and flood	231,61
2021	Cyclones Yaas, Gulab, Jawad	168,15
2022	Floods	78,09
Total		6405,54

Source: Government of Odisha: Fiscal Risk Statement, 2023

The National Institute of Disaster Management (NIDM), in its “Working Group Report: Disaster Risk Financing, Insurance, and Risk Transfer” in 2021, has quoted that in aggregate terms, economic losses in Odisha have been much higher than the SDRF, and such losses have also impacted the state GDP over the years, as shown in the following table

Table 6.2: Economic Losses, SDRF, and Orissa's Gross State Domestic Product (GSDP) over the Years in (US\$ Million)

Year	Economic losses (US\$ M)	SDRF (US\$ M)	Economic losses as % of SDRF	SGDP (US\$ M)	Economic losses as % of SGDP
2011	606	88	688	49,489	1.2
2012	0	81	0	48,975	0
2013	1,438	77	1858	50,646	2.8
2014	100	78	128	51,489	0.2
2015	1,500	116	1288	51,219	2.9
2016	333	117	285	58,473	0.6
2017	0	127	0	67,654	0
2018	316	126	250	71,965	0.4
2019	2,403	129	1862	75,459	3.2

Source: National Institute of Disaster Management (NIDM), "Working Group Report: Disaster Risk Financing, Insurance, and Risk Transfer", 2021

Based on the above information, it is evident that losses from major disasters have resulted in the failure of the State to achieve the desired growth rate in terms of GSDP.

Estimating Future Funding Gaps for Power Supply, Roads, and Bridges

As mentioned above, disaster events of the recent past, have adversely impacted the economy and the fiscal position of Odisha. The table below shows the total SDRF allocation for Odisha up to 2026, which is increasing by an average of 5% annually.

Table 6.3: Allocated SDRF of Odisha from 2021-22 to 2025-26 (in INR Crore and US\$ Million at INR = 86USD)

Year	SDRF (INR Crore)			SDRF (USD Million)		
	Central share (75%)	State share (25%)	Total	Central share (75%)	State share (25%)	Total
2021-2022	1283.2	428.0	1711.2	149	50	199
2022-2023	1348.0	448.8	1796.8	157	52	209
2023-2024	1415.2	471.2	1886.4	165	55	219
2024-2025	1485.6	495.2	1980.8	173	58	230
2025-2026	1560.0	520.0	2080.0	181	60	242
Total	7092	2363.2	9455.2	825	275	1,099

Source: OSDMA. Odisha State Disaster Management Plan, 2023. <https://www.osdma.org/state-dm-plan/#gsc.tab=0>

As a state-owned fund, the SDRF is the readily available source for post-disaster response by the state.

Other ex-post mechanisms

The recovery and reconstruction expenditure on the state's infrastructure assets is incurred by the respective state line departments. Barring some initial recovery & reconstruction expenditure financed through SDRF/NDRF. Most of this expenditure is financed through ex post budgetary reallocations or supplementary demands for grants. The expenditure is also financed through development support packages from the centre, additional provisions for centrally sponsored schemes or interest-free 50-year loans under the Scheme for Special Assistance to States for Capital Investment (SASCI).

Average Annual Losses (AAL)

In the case of Odisha, floods were identified as the hazard that can cause the highest AAL without climate change effects. Based on the catastrophe model, the annual average loss (AAL) to the **energy sector** will be due to floods at about **\$ 119.4 million**, which can be aggravated by climate change (RCP8.5) up to \$ 134 million. **For roads and bridges**, floods have the higher estimated average annual loss (AAL) which is about **\$ 19.9 million**.

Furthermore, Amongst the energy sector assets, distribution is entirely owned by the state, whereas the transmission & generation sector assets are owned by both the Centre and state entities.

The contingent liability for these assets lies with the Centre and states, depending on the ownership.

The AAL values for the distribution sector stand at \$86.26 million for floods, \$10.25 million for cyclones, and \$1.59 million for earthquakes.

Amongst the Roads & Bridges assets, contingent liabilities for major district roads, state highways, and rural & urban roads lie with the state government, while for the rest (national highways & expressways) they lie with the national government.

The total estimated AALs for rural & urban roads stand at \$24.97 million (for floods at \$14.57 million, landslides at \$8.5 million, and earthquakes at \$1.9 million), whereas for state highways & major district roads it stands at \$3.49 million (for floods at \$1.89 million, landslides at approximately \$1.5 million, and earthquakes at \$0.1 million).

Probable Maximum Losses (PML)

For the power sector, **floods with a return period of 10 years will have a PML of \$ 258.4 million**, without the effects of climate change. Those under a climate scenario of RCP8.5 can reach up to \$ 289 million. For those with a return period of 25 years, the PML is estimated at \$ 533 million, reaching \$ 592 million at the RCP8.5 scenario. **The PML for roads and bridges will be due to rain-induced landslides with a 10-year return period at \$ 48.4 million**, without climate change effects. For those with a return period of 25 years, the PML is estimated at USD 98.6 million.

For financing, the estimated losses AALs & PMLs, both a combination of *ex ante* & *ex post* mechanisms are available.

Funding Gap Scenarios

Ex ante disaster risk financing mechanisms in the state are essentially composed of the SDRF and NDRF funds available as per the recommendations of the Finance Commissions of India. Expenditures from SDRF and NDRF funds are based on MHA guidelines on items and norms of assistance. In the context of the infrastructure sector, SDRF provides only for immediate recovery and reconstruction expenses, with the rest of the reconstruction cost essentially funded by *ex-post* departmental expenditures by State line ministries.

The Central share and the state contribution of Odisha in the SDRF, as per the 16th FC Report, are as follows:

Table 6.3: Allocated SDRF of Odisha from 2021-22 to 2025-26 (in INR Crore and US\$ Million at INR = 86USD)

Fiscal year	Total SDRF	
	(INR Crore)	\$ (Million)
2026-2027	1,718	206.99
2027-2028	1,804	217.35
2028-2029	1,894	228.19
2029-2030	1,989	239.64
2030-2031	2,088	251.57

Source: 16th FC report (2026), 1\$ =83 INR

The SDRF, as per the 15th FC's recommendations, is comprised of three funding windows of Relief and Response, Recovery and Reconstruction, and Preparedness and Capacity Building. This has been revised by the 16th FC, with the window of Preparedness and Capacity Building being shifted to SDMF and only the other two windows remaining under the SDRF.

As per the 15th FC, the reconstruction and recovery window amounted to 30 percent of SDRMF or 37.5 percent of SDRF. It provided for expenditure on immediate recovery and reconstruction of infrastructure. However, the items and norms for assistance for SDRF expenditure as laid out by the MHA constitute a mere fraction of the actual recovery and replacement costs, with a major chunk of the expenditure incurred out of the budgets of infrastructure departments.

Simple Case

Based on the contingent liability estimates across the two infrastructure sectors highlighted above in post-disaster loss estimates subsection and the *ex ante* sources of financing subsection, a funding gap assessment is undertaken below using certain simplifying assumptions to illustrate the magnitude of the gap.

Assumptions

The recovery and reconstruction window is used entirely for infrastructure repairs of the two sectors and not for *ex gratia* compensation for Housing or for other infrastructure sectors.

Out of the two sectors considered, the distribution assets in the Energy sector and State highways / major district roads (MDR) and rural road assets in the Roads and bridges sectors are considered.

(Note: As per SDRF norms from MHA, recovery and reconstruction expenditure for the Housing and Infrastructure assets, subject to certain conditions, are eligible for assistance, Eg: Energy sector: Distribution lines & transformers up to 11KV and Roads sector: MDR/state highway & rural/ urban roads are eligible)

Table 6.4: SDRF and AALs for Fiscal Year 2026-2027 (US\$=83 INR)

Fiscal Year	Total SDRF	Central share 75%	State share 25%	Total SDRF (US\$ Mill)	Recovery & Recon-struction window (US\$ Mill) 37.50%	Energy (Distri-bution Assets)	Roads and Bridges (State Highway, MDR, Rural & Urban Roads)	Gap (US\$ Mi ll)	NDRF (Graded cost sharing norm for amount between 250-500 CR INR))	
									State share 20% (US\$ Mi ll)	Central share -80% (US\$ Mi ll)
2026-27	1718	1288.5	429.5	207	77.6	98.1	28.46	-48.9	9.79	39.15

Table 6.4 indicates that *ex ante* SDRF reserves lack sufficient funds to support reconstruction and recovery expenditure, even for just 2 infrastructure sectors: energy and roads and bridges. However, it is important to highlight that *ex ante* NDRF mechanisms are available along with several other *ex post* mechanisms that help finance this expenditure. However, longer disbursement time for NDRF funds and ad hocism and higher economic costs associated with *ex-post* mechanisms, such as developmental expenditure, remain a challenge.

Extreme cases

In analysing the potential funding gap after a disaster, an extreme scenario involving tropical cyclones and floods with a 10-year return period was considered. This approach assumes the least-cost scenario, as hazards with longer return periods have higher PMLs. Assumptions for Extreme case scenarios:

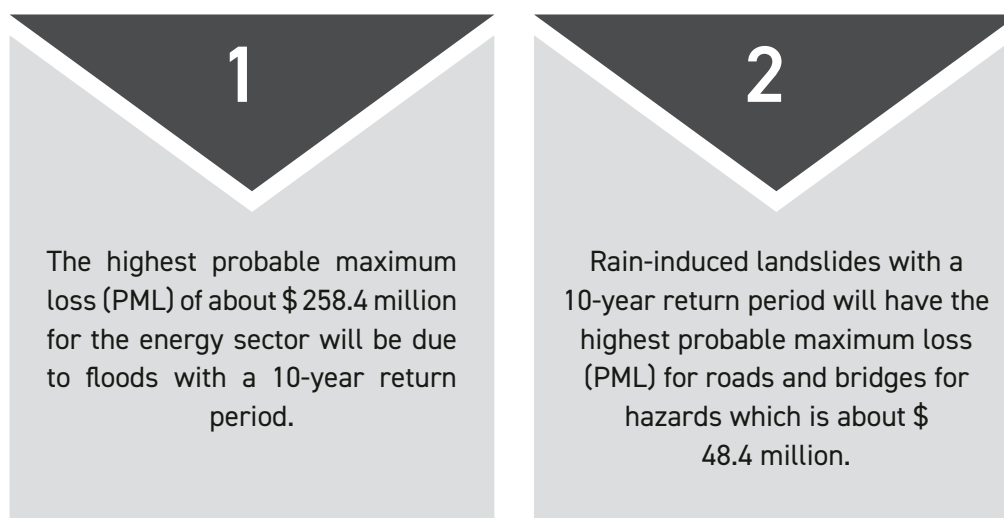
The recovery and reconstruction window is used entirely for infrastructure repairs of the 2 sectors and not for *ex gratia* compensation for Housing or for other infrastructure sectors.

The 2 Sectors - Roads and bridges and Energy - are considered in entirety. Assets have not been segregated based on contingent liabilities lying with the state or centre, as in these extreme cases. Both the state and central liability and sources need to be looked at and analyzed together.



Scenario 1.

Hazards with a return period of 10 years, excluding climate change effects, are projected for the years 2026-27. This analysis assumes the least-cost scenario, as hazards with longer return periods have higher PMLs. This scenario considers the following:



Based on the above considerations, the following table compares the funding gap for Odisha with, and without, the central government's support.

Table 6.5: Annual SDRF and the highest PMLs for energy, and roads and bridges for hazards with a 10-year return period

SDRF (INR Crore)			SDRF (US\$ Million)		PML (US\$ Million)		Gap/Surplus (US\$ 'Million)	NDRF (Graded cost sharing norm for amount above 500 CR INR))	
Total SDRF	Central Share (75%)	State share (25%)	Total SDRF	Recovery & Reconstruction window (37.5%)	Energy	Roads and bridges		State share (25%) (US\$ Mill)	Centre share -75% (US\$ Mill)
1718	1288.5	429.5	207	77.6	258	48	-228.38	57.09	171.28

Exchange rate- 1\$ =83 INR

Table 6.5 indicates that the SDRF cannot accommodate even 50% of the PML for the energy, roads and bridges sectors if such 10-year return period hazards occur in the same year. Furthermore, the NDRF mechanism gets stretched, with state share under NDRF exceeding 50 Mill USD just for these 2 sectors.

Scenario 2.

Hazards with various return periods without climate change projected impacts and with the highest PMLs occurring in the same year, say 2026-2027. This scenario considers the following data from the catastrophe model:

1

For the energy sector, floods with 10- to 1000-year return periods will cause the highest PML. Tropical cyclones with 2,500- and ,5000-year return periods will have the highest PMLs.

2

For roads and bridges, rain-induced landslides with 10- to 500-year return periods will have the highest PML. Earthquakes with 1000- to 5000-year return periods will cause the highest PMLs.

3

The total state disaster response fund for the year is around USD 207 Million (SDRF central and state share).

Based on the above considerations, the table below shows that if hazards with the highest PMLs by various return periods occur within the same year, there will be a huge funding gap for the state.



Table 6.6: Funding Gap Based on Highest PMLs by Return Period (no Climate Change)

Return period	SDRF (INR Crore)			SDRF in US\$ (Mill)	Recovery & Reconstruction window (US\$ Mill)	PML (US\$ 'Mill)		Gap/Surplus (US\$ 'Mill)	NDRF (Graded cost sharing norm for amount above 500 CR INR))	
Years	Total SDRF	State Share	37.50%	Total SDRF	37.50%	Energy	Roads and bridges		State share (25%) (US\$ Mill)	Centre share (75%) (US\$ Mill)
10	1718	429.5	644.25	207	77.62	258	48	-228	57	171
25	1718	429.5	644.25	207	77.62	533	99	-554	139	416
50	1718	429.5	644.25	207	77.62	739	137	-798	200	599
100	1718	429.5	644.25	207	77.62	808	152	-882	221	662
250	1718	429.5	644.25	207	77.62	826	160	-908	227	681
500	1718	429.5	644.25	207	77.62	838	167	-927	232	696
1,000	1718	429.5	644.25	207	77.62	851	227	-1,000	250	750
2,500	1718	429.5	644.25	207	77.62	906	370	-1,198	300	899
5,000	1718	429.5	644.25	207	74.01	1,065	534	-1,525	381	1144

Exchange rate- 1\$ =83 INR

Considering the factors mentioned above, Table 6.6 indicates that if hazards with the highest PMLs occur within the same year across various return periods, there will be a significant funding gap for the state, which would require a lot of ex-post mechanisms & considerable impact on state and central finances.



Chapter 7

Recommendations



Recommendations

This report presents the following recommendations to mitigate fiscal risks related to disasters affecting critical infrastructure sectors in Odisha. These suggestions are based on the financial data and findings presented in various chapters of this report.

1 Fiscal Policy Adjustments and Post-Disaster Financial Planning

a Adjusting tax revenue forecasts

Natural hazards have a detrimental effect on tax revenue collection, often resulting in significant shortfalls compared to expected revenue. For effective future fiscal planning, it is essential to consider the potential decline in revenue that can occur after disasters. This involves conducting a comprehensive analysis of historical tax collection patterns following such events and adopting more flexible forecasting methods that can adjust to sudden economic disruptions caused by these disasters.

b Managing post-disaster debt growth through structured borrowing

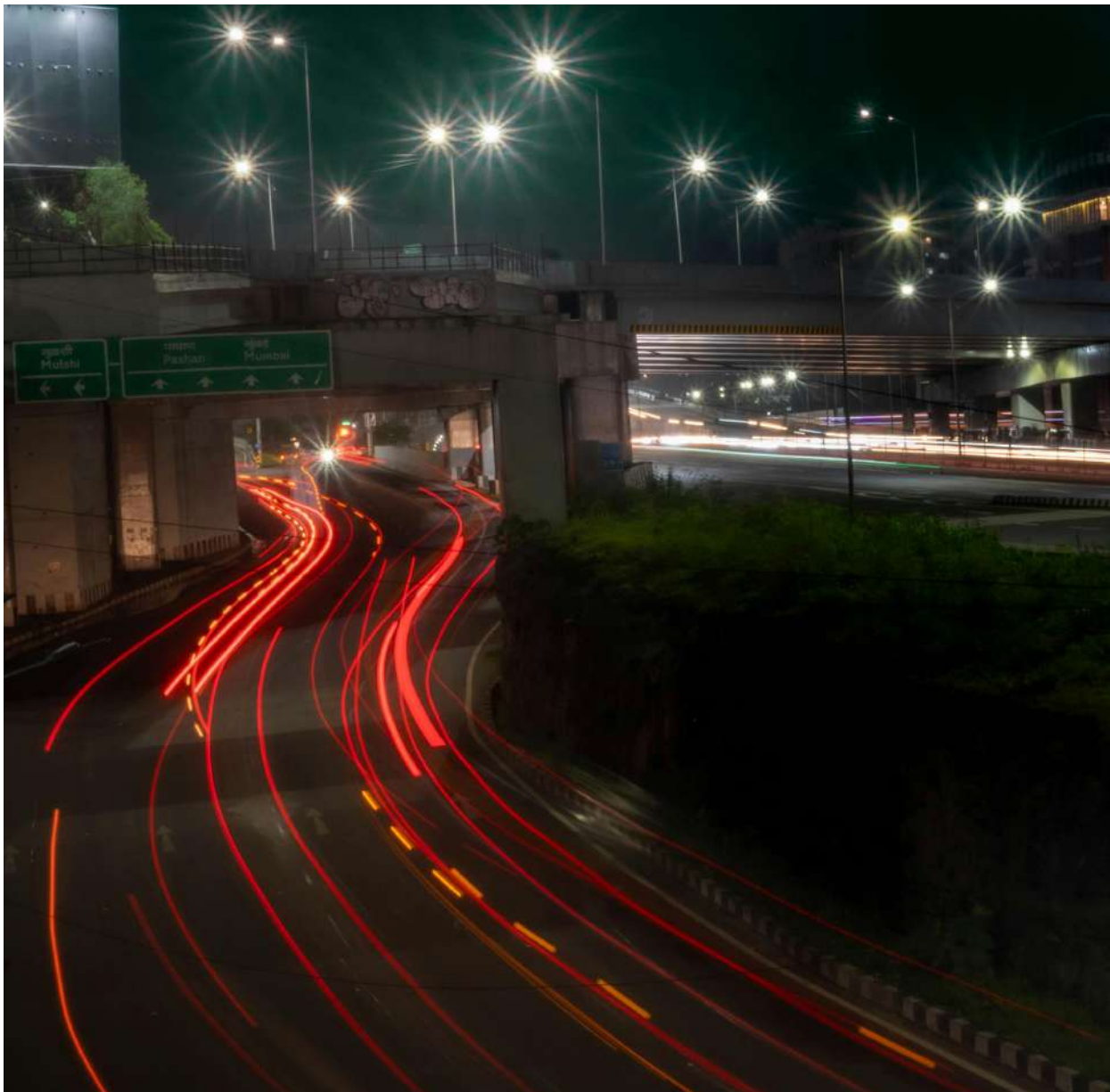
Post-disaster financial recovery typically requires an increase in total expenditure. Projections suggest that the costs could increase by approximately \$467.7 million if a disaster like the devastating Super Cyclone of 1999 were to occur again. To mitigate the financial strain of reconstruction efforts, the government should seek concessional financing arrangements with multilateral institutions, including the World Bank and ADB. By securing low-interest loans specifically designed for reconstruction, the state can manage its debt growth more effectively.

c Enhancing Central grant utilization and fund disbursement

Odisha's strong fiscal consolidation and debt reduction has provided it with the fiscal space to provide adequate funds in the post-disaster recovery from any natural hazards. This has allowed it to reduce its dependence on NDRF. Looking ahead, Odisha should enhance utilization of the federal grants and ensure its swift disbursement. Current models indicate that grants from the Central Government generally increase by around 1.8 percent following a disaster. The state can negotiate and establish a pre-approved disbursement mechanism with the Central Government. This would allow for rapid access to necessary funds immediately following a disaster, thereby enhancing the state's ability to respond effectively and efficiently.

d Explore the possibility of establishing contingent credit lines

This innovative approach enables governments to quickly mobilize funds for recovery and relief efforts without undergoing a lengthy approval process. Odisha could consider negotiating similar pre-arranged credit lines to improve its fiscal response capacity, allowing it to respond more efficiently and effectively to hazards. Given the broad funding gap for potential damage and losses from extreme disasters, expanding the sources of contingent credit will have a positive impact on post-disaster recovery. One way to do this is to structure a sub-national budget support program focusing on climate resilience and then have policy actions that support the setting up a CAT-DDO and its funding. Whereas another alternative is for state financial intermediary to tap MDB funding for a CAT-DDO.



2 Risk-Informed Infrastructure Investments and Climate Resilience Strategies

a Continue to advocate for disaster preparedness and climate friendly practices among the population to build resilience

Understanding disaster and climate risks, along with community-based disaster risk management, is essential for local governments and communities to effectively prepare for and mitigate the adverse effects and impacts of natural hazards. This proactive approach can significantly lessen the fiscal risks associated with natural hazards coverage.

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

Odisha should identify critical assets and assess the potential damage they may face from frequent and extreme disasters. Additionally, it is essential to evaluate the impacts on other important sectors of the economy to determine the appropriate risk management mechanism for the state. This assessment will facilitate further analysis and help identify appropriate financial risk management mechanisms, including which risks can be retained and which can be transferred. Annexed is a list of disaster risk financing mechanisms.

c Upgrade and update hazard maps

To encourage insurance companies to expand their disaster-related insurance coverage, it is essential to have updated hazard maps. These updated or upgraded all-hazard maps are crucial for insurance companies because they help in risk assessment, pricing, underwriting, among other functions. By identifying high-risk areas prone to floods, earthquakes, cyclones, and other disasters, insurers can determine risk levels and assess coverage eligibility based on the risk exposure of a property. Additionally, these maps allow insurers to design customized policies for different risk zones, estimate potential losses, and maintain adequate financial reserves or reinsurance, and set appropriate premiums for policyholders. Thus, it is crucial for the state to continuously update and upgrade hazard maps to encourage insurance companies to provide various types of disaster-related coverage.

d 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 integrate disaster risk management and the impacts of climate change into the planning and investment strategies of both the government and the private sector. Development plans and investments should consider the building codes, land-use plans, and zoning regulations mentioned earlier.

e Strengthening infrastructure resilience through dedicated budgeting

Odisha has faced significant financial losses in its power sector, with damages exceeding \$ 381 million as a result of recent cyclonic events. To mitigate such losses in the future, the state government should establish mandatory resilience funds specifically earmarked for infrastructure projects. This initiative would ensure that all new public infrastructure investments incorporate disaster-proof designs tailored to withstand extreme weather events. Additionally, older structures should be retrofitted to improve their durability and resilience, ultimately decreasing their vulnerability to future hazards.

f Sector-specific investment in transport infrastructure

The impact of extreme weather events on transportation infrastructure has been clearly demonstrated by Cyclone Phailin in 2013, which resulted in approximately \$111.73 million in road damages. This was followed by Cyclone Fani in 2019, which resulted in losses of \$75.52 million. To counteract these recurrent damages, it is crucial to prioritize investments in climate-resilient transport mechanisms. This includes constructing elevated roads and climate-resistant bridges, as well as improving drainage systems to prevent flooding. Such investments are critical not only for enabling safer transport but also for reducing the fiscal burdens associated with frequent infrastructural damages.



3 Strengthening Financial Resilience Through Risk-Based Planning

a Increasing pre-disaster investment

Odisha faces significant financial risks due to flooding, with an estimated loss of \$621 million projected for a 1-in-50-year flood. This estimate highlights the urgent need for increased financial allocations to address these vulnerabilities. Additionally, upgrading critical infrastructure, such as roads, bridges, and drainage systems, is essential for mitigating the impact of future floods. Proactive investment in these areas has the potential to significantly reduce economic losses and help protect communities from the devastating effects of flooding.

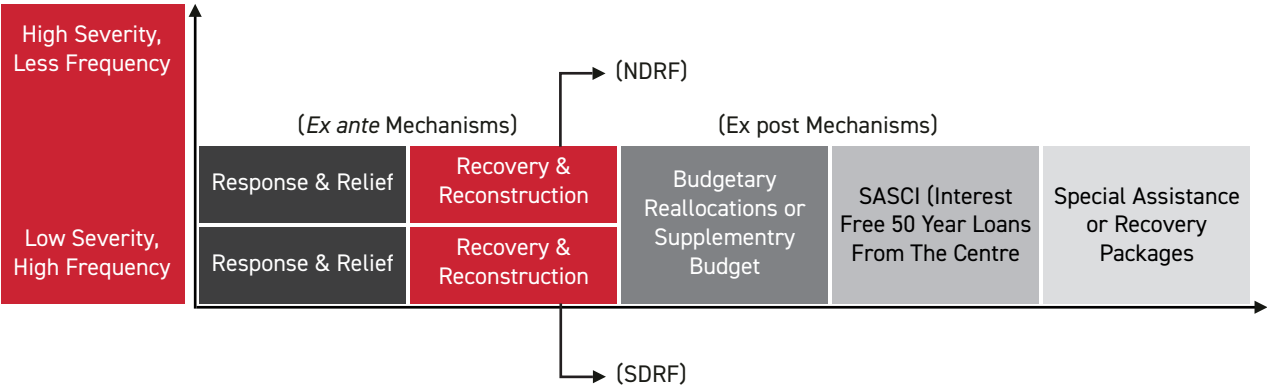
b Building a state-wide disaster risk database

To improve the financial planning process for disaster management and recovery, Odisha should prioritize the development of a comprehensive digital database. This database would compile critical information on disaster impacts, including in-depth assessments of fiscal expenditures resulting from past disasters and detailed reports on infrastructure damages. By establishing such a robust digital risk database, the state will be better positioned to conduct thorough risk assessments, enabling more informed budgeting decisions for future contingencies and improving overall disaster preparedness.



4 Establishing a Dedicated Disaster Risk Financing Strategy

The Disaster Risk Finance layering in the state is as follows (Indicative):



The study reveals that there is heavy reliance on ex-post budget reallocations and central assistance, with limited pre-arranged financing and growing post-disaster funding gaps, particularly in the power and transport sectors. The state may adopt a three-tier risk layering framework:

- A** Low-risk/high-frequency events: Budget contingencies and dedicated reserve funds (e.g., augment or allocate relief and rehabilitation fund beyond the SDRF with clear trigger rules).
- B** Medium-risk/moderate-impact events: Expand existing parametric insurance coverage or explore and other schemes.
- C** High-risk/low-frequency catastrophic events: Secure contingent credit lines and standby loans from other sources for rapid liquidity in accordance with existing laws.

Additionally, for rare yet catastrophic events that could have severe economic implications, the state should consider issuing catastrophe bonds. These bonds would help the state to raise capital from investors, ensuring that adequate funds are available promptly to address the aftermath of high-impact disasters. Lastly, annual risk-layering reviews should a part of the budget process, integrated into the state's fiscal strategy.

a Develop a sovereign catastrophe insurance pool

Inspired by initiatives like the Caribbean Catastrophe Risk Insurance Facility (CCRIF), Odisha has the opportunity to join forces with other disaster-prone states across India to create a sovereign catastrophe insurance pool. This collaboration would distribute the financial risks associated with natural hazards, enabling states to share the costs and benefits of insurance coverage. By leveraging economies of scale, such a pool could offer more affordable insurance premiums, ensuring that participating states are better equipped to respond to and recover from disasters without overburdening their individual budgets.

b Strengthen the role of parametric insurance

Cyclone Fani, which struck in 2019, caused significant financial damages to Odisha's power infrastructure, totalling approximately \$75.52 million. To mitigate such substantial losses in the future, it is essential to expand the scope of parametric insurance. By incorporating parametric insurance into its financial toolkit, Odisha could significantly enhance its disaster response capabilities. This type of insurance, successfully implemented by initiatives like the African Risk Capacity (ARC) and the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), operates based on predefined parameters or triggers related to specific disaster events. For example, parametric insurance provides immediate liquidity following extreme weather events by activating payouts as soon as certain thresholds – such as wind speeds or rainfall levels – are met. This immediacy is crucial in disaster scenarios, enabling faster recovery and minimizing economic disruption for affected communities.

c Study further the expansion of parametric insurance coverage

The state can further review the Afat Vimo microinsurance scheme. A survey conducted by the All-India Disaster Mitigation Institute (AIDMI) highlighted that policyholders were able to use their payouts to repair their damaged homes, which in turn strengthened their resilience to extreme weather events. However, the same survey also revealed that there is a lack of awareness among the target community about the potential benefits of insurance, as well as confusion regarding the claims process (Action on Climate Today 2016). On the other hand, Odisha can consider adopting Nagaland's parametric insurance model (Bindal et al. 2021). This approach will reduce the government's financial burden for post-disaster rehabilitation and encourage policyholders to engage in preparedness and mitigation measures.

d Explore the possibility of a mandatory insurance

In India, there is currently no regulation requiring mandatory insurance when purchasing a property, whether residential or commercial. Presently, fewer than 1 percent of homes in India are insured. The option of making property insurance mandatory can be studied, similar to how banks and financial institutions require loan protection insurance for auto loans when securing property loans (Upadhyay 2023). Additionally, the state may consider requiring residential properties, businesses, or specific industries operating in defined disaster-prone areas – such as those businesses located in flood-prone areas – to have flood insurance coverage.

e Leveraging international climate finance and green bonds

With the expectation of increased frequency and intensity of hazards due to climate change, Odisha must take proactive steps to secure global climate finance. Engaging with established international funding mechanisms, such as the Green Climate Fund (GCF), offers a valuable opportunity to obtain the necessary capital for sustainable infrastructure and disaster preparedness projects. In addition, issuing green bonds can serve as an innovative financing strategy to raise funds specifically aimed at enhancing resilience against environmental impacts while promoting sustainable development within the state. By leveraging these financial tools, Odisha 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 Lanka⁴

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 placed for Taprobane Seafood Group, Sri Lanka's largest seafood company, helping it meet a critical condition to secure \$15 million in project financing from 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 has enabled Taprobane Seafood Group to meet a critical condition to secure \$15 million in project financing from Dutch entrepreneurial development bank FMO.

WTW has 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.



⁴ Press Release. "WTW Launches Asia's First 4-Peril Parametric Insurance Solution to Unlock Financing for Aquaculture Development." 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>.

Thailand⁵

Since 2011, the Thailand Rice Disaster Relief Top-up Crop Insurance Scheme, using 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 is linking remote sensing technology to sophisticated crop yield modelling technology to build a rice production monitoring system that provides accurate and timely information on rice areas, yield, and disaster-affected rice areas.

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 managed by the Agriculture Insurance Company of India (AICI). It provides insurance for food crops, oilseeds, and a few commercial crops using an area yield-based approach.⁴ By comparing current crop yields with historical data, this indexed strategy provides indemnity payouts to farmers who are insured in specific locations if actual yields are lower than historical levels. In addition to addressing issues with tiny landholdings, the plan lessens moral hazard and adverse selection. NAIS, however, is dependent on government contributions provided after a disaster and subsidized premiums. As a result, the government has an unlimited financial risk and claims settlement delays could lead to hardship for farmers. To enhance the programme's effectiveness and address these challenges, the government collaborated with AICI and sought technical assistance from the World Bank in 2005 to modify and improve insurance coverage.



⁵ The World Bank. Disaster Risk Financing and Insurance Case Study – National Agricultural Insurance Scheme in India. 2011. https://www.farm-d.org/app/uploads/2019/05/DRFI_India_mNAIS_Jan11

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 Mahbubnagar district of Andhra Pradesh. This innovative insurance programme provided coverage based on rainfall levels, helping farmers mitigate risks associated with unpredictable weather conditions. It functions as a significant mechanism for disaster risk financing and insurance by providing 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 utilizing weather indices as triggers for payouts, the insurance scheme ensures timely compensation to farmers, enabling them to mitigate the economic impact of climate-related disasters. Since then, weather-based crop insurance has evolved significantly in India, with various programmes and approaches aimed at supporting farmers during adverse weather events. For instance, more recent initiatives include heat-linked parametric insurance systems that offer a lifeline to Indian women in the informal sector.^{6,7} This approach not only promotes resilience among agricultural communities but also helps stabilize livelihoods and fosters sustainable development in vulnerable regions. Additionally, by pioneering such initiatives, ICICI Lombard contributes to the evolution and expansion 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'⁸ 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 speed up the processing and payment of claims, improve technology interventions, and provide states more freedom in choosing risk covers and the distribution of 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 hazards and pests. It also seeks to use smartphones and remote sensing technology to speed up crop loss estimation.⁹ In general, PMFBY seeks to uphold contemporary farming methods, stable farmer income, encourage sustainable agricultural production, and guarantee the flow of financing to the agriculture sector for 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.

⁶ Clarke, D. J., O. Mahul, N. K. Rao, and N. Verma. Weather-Based Crop Insurance in India. Policy Research Working Paper. World Bank, 2012. <https://documents1.worldbank.org/curated/en/693741468269445619/pdf/WPS5985.pdf>.

⁷ ICICI Foundation. Financial Inclusion. n.d.

⁸ Government of India. PM Fasal Bima Yojana. 2020. <https://www.mygov.in/campaigns/pmfbby/>.

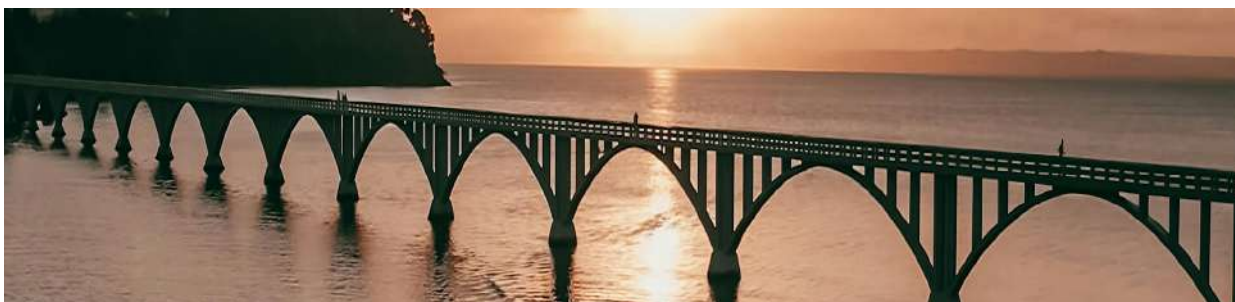
⁹ Kaur, Sandeep, Hem Raj, Harpreet Singh, and Vijay Kumar Chattu. "Crop Insurance Policies in India: An Empirical Analysis of Pradhan Mantri Fasal Bima Yojana." *Risks* 9, no. 11 (2021): 191. <https://doi.org/10.3390/risks9110191>.

Philippines¹⁰

Aside from the multiple-peril crop insurance (MPCI), the country also has an all-peril property cover for public assets, which is 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, etc.).

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 Philippines. Through a CAT-DDO, the Philippines can access funds upon the declaration of a national state of calamity due to an imminent or occurring natural catastrophe or a declaration of a state of public health emergency. The loan is available for a period of three years and can be renewed for up to a total period of 15 years. The past CAT-DDOs have all been successfully disbursed to propel the Philippines towards recovery in the aftermaths 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 World Bank 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 hazards and health crises, mitigating their impact on the economy. The funds can be disbursed when the president declares a state of calamity in response to a natural disaster or public health emergency.

Catastrophe Bond.¹¹ In November 2019, the World Bank issued to capital market investors two tranches of cat bonds that provide the Philippines with insurance coverage of a maximum of \$225 million (\$75 million for earthquakes and \$150 million for tropical cyclones) for three years. The type of events that will trigger a payout are predefined based on the requirements of the country. 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 during the life of the bond, removing the uncertainty of the cost.



¹⁰ Philippines, Department of Finance. Annual Report. 2023.

¹¹ World Bank. Case Study: The Philippines – Transferring the Cost of Severe Hazards to Capital Markets. n.d.

Mongolia

In 2006, the Government of Mongolia, with assistance from the World Bank, implemented a pilot programme in three provinces for an index-based insurance programme to address death rates in the livestock population. Shocks to the well-being of animals have devastating implications for the rural poor and for the overall economy. The scheme combines self-insurance, market-based insurance, and social insurance. Herders pay a premium rate for a commercial risk product (base insurance product), which has specified trigger percentages for livestock mortality rates, while 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 beyond the financial capacity of the pool through a reinsurance treaty with the World Bank.

Mexico¹²

Mexico has 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:

The **Natural Disaster Fund (Fondo de Desastres Naturales, FONDEN)** consists of the Emergency Fund (Fondo para la Atención de Emergencias FONDEN), the Natural Disaster Fund Programme of 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-incoming housing; and (iii) certain components of the natural environment (e.g., forestry, protected natural areas, rivers, and lagoons).

Natural Disaster Prevention Fund (Fondo para la Prevención de Desastres Naturales, FOPREDEN) includes the Preventive Trust (Fideicomiso preventivo, FIPREDEN), aimed at promoting and strengthening preventive actions for disaster risk reduction (DRR), diminishing the effects and impacts of natural phenomena, as well as fostering DRR research. FIPREDEN provides resources to the agencies, federal and state units, for unscheduled preventive actions.

¹² UNDP (United Nations Development Programme). Mexico: Country Case Study Report – How Law and Regulation Support Disaster Risk Reduction. June 2014; World Bank. FONDEN: Mexico's Natural Disaster Fund – A Review. 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 Assistance to Micro, Small, and Medium Enterprises (**Fondo de Apoyo para la Micro, Pequeña y Mediana Empresa (MIPYMES) (Fondo PyME)**), among many other modalities, provides resources to relieve the effects caused by disasters to affected firms. This facilitates timely attention in the case of an emergency. The National Entrepreneur Institute (Instituto Nacional del Emprendedor, INADEM) operates the PyME Fund. It provides help to damaged firms through the Special Programme for Economic Reactivation in the case of contingencies (Programa especial de reactivación económica por contingencias).

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

FONDEN resources are leveraged with market-based risk transfer instruments. Despite its stable annual budget appropriation, funding needs related to the occurrence of one or multiple disasters can cause a shortfall in any given year. To manage the volatility of demand on its resources, FONDEN is allowed to 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 applies a variety of tools to assist local governments and organizations in responding to hazards such as 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 multiple risks in multiple regions after the CatMex attained maturity in 2009. Using the World Bank's recently formed MultiCat Program, 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 2009.¹³ 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.¹⁴ This sovereign catastrophe bond not only enhances Mexico's financial resilience to hazards but also sets a precedent for other countries seeking innovative approaches to disaster risk financing and insurance.

Component for the Attention of Hazards (CADENA) Mexico (2003)

In Mexico, hazards, 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 the segmentation of the farming sector, where small-scale farmers form a significant portion but face difficulties 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 requiring insurance for financing, farmers able to pool risks and access credit, and small-scale, vulnerable farmers lacking access to credit or insurance. The CADENA Program, launched in 2003, operates as a crucial mechanism for disaster risk financing and insurance by providing formal parametric crop and livestock insurance solutions at the state level, 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).¹⁵ By doing so, it replaces ad hoc post-disaster relief schemes with a structured insurance approach, mitigating the financial impacts of hazards on agriculture. This programme not only provides financial protection but also promotes resilience among vulnerable farming communities, contributing to Mexico's overall disaster preparedness and response capabilities

¹³ The World Bank. A Case Study of Insuring Against Natural Disaster Risk in Mexico. 2015. <https://documents1.worldbank.org/curated/en/170311468056076924/pdf/81172-REVISED-Mexico-MultiCatBond-2015>.

¹⁴ The World Bank. Disaster Risk Financing and Case Study – Mexico MultiCat Bond. 2013. <https://openknowledge.worldbank.org/server/api/core/bitstreams/42f4a9ed-6f3d-5bbb-bb5b-e5c2cc6703ae/content>.

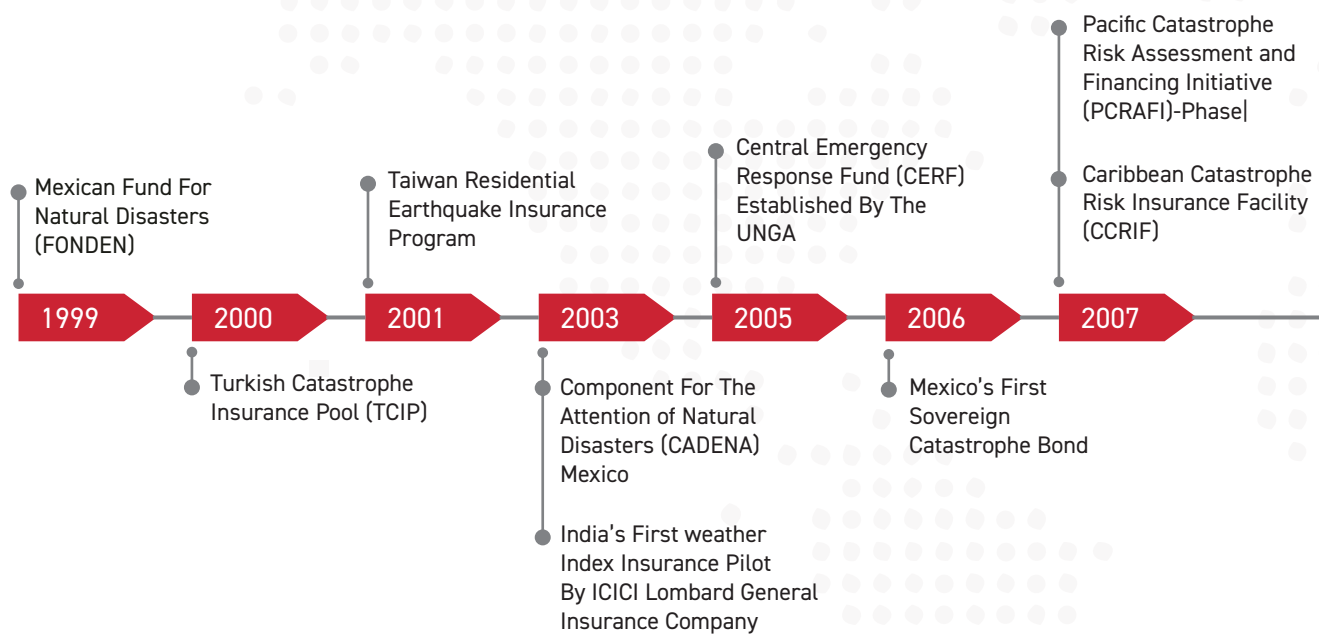
¹⁵ The World Bank. Mexico Agriculture Insurance Market Review. 2013. <https://documents1.worldbank.org/curated/pt/124521468287160777/pdf/881000BRIOP1300urance04Pager0Cadena>.

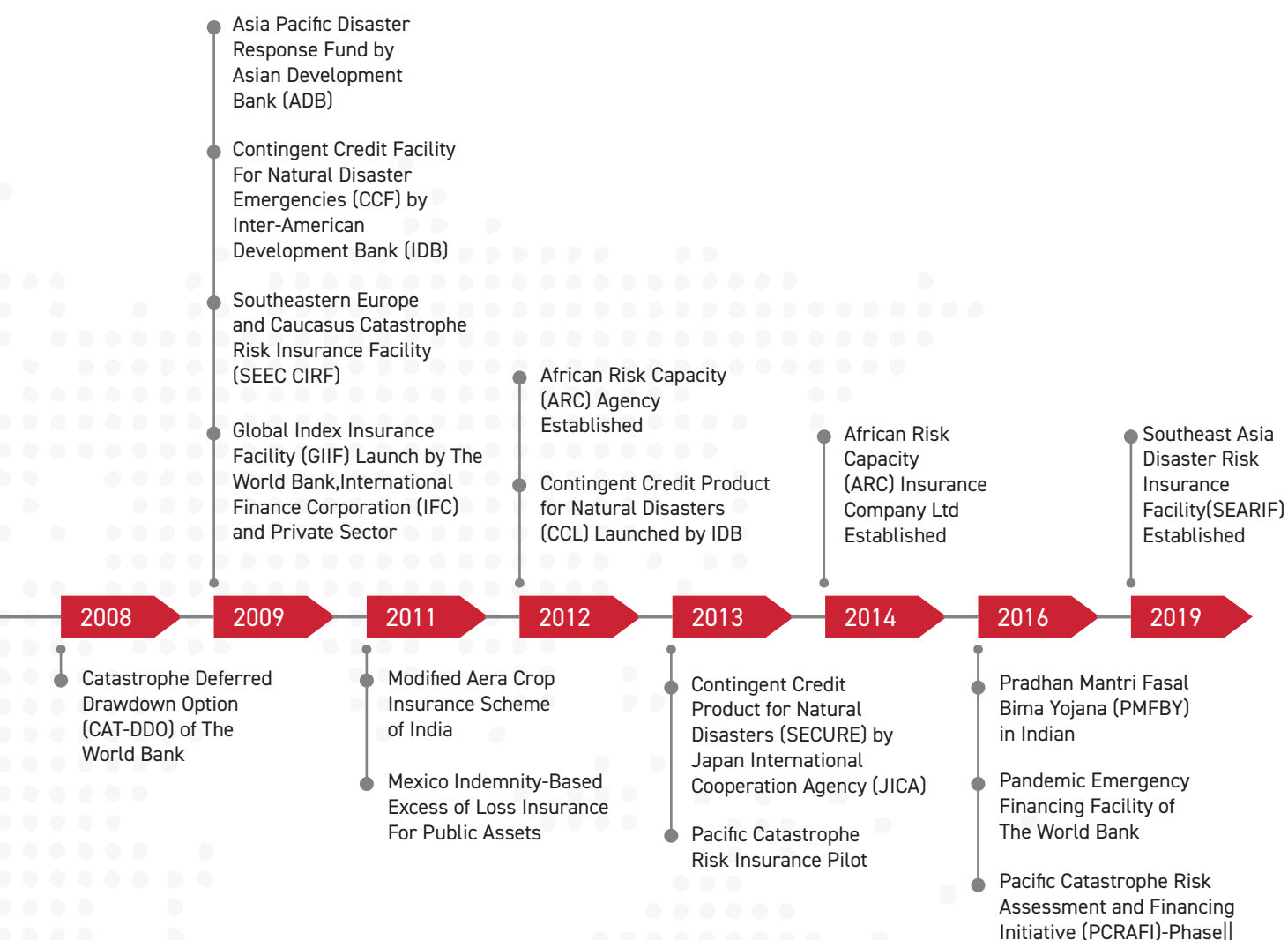
Mexico Indemnity-based Excess of Loss Insurance for Public Assets

Mexico has established an innovative insurance scheme to lessen the financial damage that natural catastrophes cause on 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 information from simulated losses. It has an excess-of-loss insurance component based on indemnification that activates when demands linked to disasters reach a certain threshold. To increase resilience to hazards, Mexico's programme works in combination with risk reduction initiatives, such as bolstering early warning systems, in addition to its primary goal of protecting the government budget.¹⁶ 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 supporting early warning systems, enhances resilience to hazards, further emphasizing its role in comprehensive disaster risk management and financial protection

¹⁶ The World Bank. Quantifying Contingent Liabilities Associated with Hazards. 2013. <https://documents1.worldbank.org/curated/en/672271467997574054/pdf/97977-BRI-Box391499B-PUBLIC-Short-Note-1-Risk-Assessment-04Nov2013>.







Türkiye

Turkish Catastrophe Insurance Pool (TCIP-2000)

The Turkish Catastrophe Insurance Pool (TCIP) functions as a pivotal mechanism for disaster risk financing and insurance by providing coverage against hazards 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 away from the government and onto private insurers. To facilitate this transition, the World Bank provided crucial financial and technical support for the establishment of the Turkish Catastrophe Insurance Pool (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 in bolstering disaster resilience and easing the strain on government resources in the face of 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 response in times of crisis while fostering long-term resilience and sustainability.¹⁷

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 offers basic insurance protection against earthquakes starting from 1 April 2002. The programme serves as a vital mechanism for disaster risk financing and insurance by providing coverage specifically tailored to earthquakes for residential properties. Homeowners who experienced earthquake damage can 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 programme and the managing entity for the Risk Spreading Mechanism of Residential Earthquake Insurance in order to implement TREIP and give homeowners basic earthquake insurance protection.¹⁸ This not only facilitates financial protection for individual homeowners but also contributes to overall community resilience by encouraging earthquake-resistant construction practices and facilitating rapid recovery in the aftermath of seismic events. By pooling resources and spreading risk across a broad base, the programme enhances Taiwan's disaster preparedness and response capabilities, ultimately fostering a more resilient society.

¹⁷ The World Bank. Disaster Risk Financing and Case Study – Turkish Catastrophe Insurance Pool. n.d. www.gfdrr.org/drfi

¹⁸ About TREIF. Webpage of Taiwan Residential Earthquake Insurance Fund. <https://www.treif.org.tw/>.



Caribbean Catastrophe Risk Insurance Facility (CCRIF-2007)

The Caribbean Catastrophe Risk Insurance Facility, the first multi-country risk pool in the world, was established in 2007 and was the first insurance product to successfully develop parametric policies backed by both traditional and capital markets. To enable the offering of new products and expansion into new geographic areas, the facility underwent a restructuring in 2014 and became a segregated portfolio company (SPC), which is 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 natural hazard 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 hazards.¹⁹



¹⁹ CCRIF SPC. The Annual Report of CCRIF SPC (2022–2023). 2023. https://www.ccrif.org/sites/default/files/publications/annualreports/CCRIFSPC-Annual-Report-2022-2023_lowres



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

A regional initiative called the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) programme was launched in 2007 with the aim of strengthening the Pacific region's financial resilience to risks of disaster and climate change. The PCRAFI facility and the PCRAFI Technical Assistance Programme are the two main pillars of Phase II, which was started in April 2016. The holistic approach of PCRAFI helps countries better understand and quantify their vulnerability to natural hazards by facilitating the development of risk assessment tools like the Pacific Risk Information System (PacRIS). The Secretariat of the Pacific Community (SPC) is undertaking a project under the technical assistance programme that focuses on capacity building for the Hazard and Exposure Database. Through in-country surveys, improved data collection capabilities, and case studies highlighting the value of risk information, this project seeks to update data in the Pacific Risk Information System (PacRIS) and eventually empower nations to independently impact data and improve their future exposure.²⁰



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

The World Bank's Flexible Loan product called the Drawdown Option (CAT-DDO) is designed to improve countries' crisis preparedness and responsiveness to natural 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 offers immediate liquidity once triggered, 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 Catastrophe-Deferred Drawdown Option (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 hazards. The CAT-DDO also helps Serbia's catastrophe insurance industry grow by offering financial safety nets and short-term funding for emergency response.²¹

²⁰ The World Bank. PCRAFI: Catastrophe Risk Assessment Methodology. 2013. <https://reliefweb.int/report/world/pacific-catastrophe-risk-assessment-and-financing-initiative-pcrafi-risk-assessment>

²¹ 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 natural catastrophes. These funding help 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 address 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.²² Assistance is eligible if certain emergency requirements are satisfied, such as a natural disaster occurring, an official declaration of emergency beyond the nation's ability 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 capability, and the cumulative effect of previous catastrophes on the country's ability to respond are among the factors that influence the size of the award.²³



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 successfully managing the financial risks connected to natural catastrophes is the Contingent Credit Facility (CCF) for Natural Disaster Emergencies. It functions as a critical mechanism for disaster risk and financing insurance by providing member countries of IDB with access to contingent loans following verified disaster events. It provides contingent loans that are reimbursed upon the occurrence of a catastrophic event, giving money for the provision of essential amenities and humanitarian relief. Countries need to have a Comprehensive Natural Disaster Risk Management Programme (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 towards proactive disaster risk management. It focuses on giving prompt financial support during the emergency phase of disasters.²⁴

²² Asian Development Bank. Funds and Resources – Asia Pacific Disaster Response Fund. <https://www.adb.org/what-we-do/funds/asia-pacific-disaster-response-fund-apdrf>

²³ NDC Partnership. Asia Pacific Disaster Response Fund. <https://ndcpartnership.org/knowledge-portal/climate-funds-explorer/asia-pacific-disaster-response-fund-apdrf>

²⁴ Collich, G., R. Rosillo, J. Martínez, D. J. Wald, and J. J. Durante. "Financial Risk Innovation: Development of Earthquake Parametric Triggers for Contingent Credit Instruments." In *Hazards and Climate Change*, edited by 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)

In order to address the lack of insurance coverage for natural hazards in Southeast Europe (SEE), a region that is extremely 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.²⁵ 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 is composed with two components: taking part in the SEEC CRIF, which supports countries in their efforts to join Europa Re, and receiving technical assistance from donors that is carried out by Europa Re. This assistance includes risk mapping, product design, weather monitoring, and legislative reforms.²⁶ 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) launch by the World Bank, International Finance Corporation (IFC), and Private Sector (2009)

The European Union, Japan, and the Netherlands support the Global Index Insurance Facility (GIIF), which is managed by the World Bank Group and aims to improve financing accessibility for microfinance institutions, small-scale farmers, and microentrepreneurs in developing nations. GIIF was established in 2009 as 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.²⁷ Through its initiatives, GIIF has enabled billions of dollars in funding, millions of contracts affecting tens of millions of people globally, and the promotion of resilience and financial inclusion in disadvantaged communities.²⁸ A crucial part of GIIF is index-based insurance, which eliminates the difficulties involved in estimating individual losses by relying on predetermined indices to initiate payouts and ensuring faster claims processing. The 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

²⁵ GEF (Global Environment Facility). 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>.

²⁶ Webpage of 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>.

²⁷ The World Bank. Global Index Insurance Facility – Overview. 2024. <https://www.indexinsuranceforum.org/overview>.

²⁸ InsuResilience Global Partnership. The Global Index Insurance Facility (GIIF). 2017.



African Risk Capacity Agency (ARC) (2012)

The African Risk Capacity (ARC) Group comprises 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, which consists of 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 natural 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, and capacity building to increase resilience against natural 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.²⁹ Through ARC, member states can access readily available funds for response, reducing reliance on external aid and ensuring timelier and more equitable disaster relief. By merging traditional disaster relief approaches with modern finance mechanisms like 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 improve their financial resilience to climate and catastrophe risks and have access to finance options for disaster risk. SEADRIF was founded in Singapore as a trust to own a general insurance business. It offers financial and consultancy services for 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.³⁰ SEADRIF facilitates cooperative methods for improving 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 programmes and products that cater to a range of demands in the ASEAN area at varying stages of development. Through programmes 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.³¹

²⁹ African Risk Capacity. About ARC. <https://www.arc.int/about>.

³⁰ 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-drmhbtokyo>.

³¹ 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 that was managed by the World Bank and now officially closed – 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 frontline responder organizations that had been pre-approved, such as UNICEF and WHO.³²



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.³³ It operates as a crucial mechanism for disaster risk financing and insurance by providing rapid and 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.³⁴ Through its proactive approach to financing emergency response, CERF plays a vital role in strengthening global disaster preparedness and resilience, ultimately contributing to more effective disaster risk management worldwide.

³² 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>.

³³ UN Central Emergency Response Fund. About CERF. <https://cerf.un.org/>.

³⁴ 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 Disadvantages³⁵

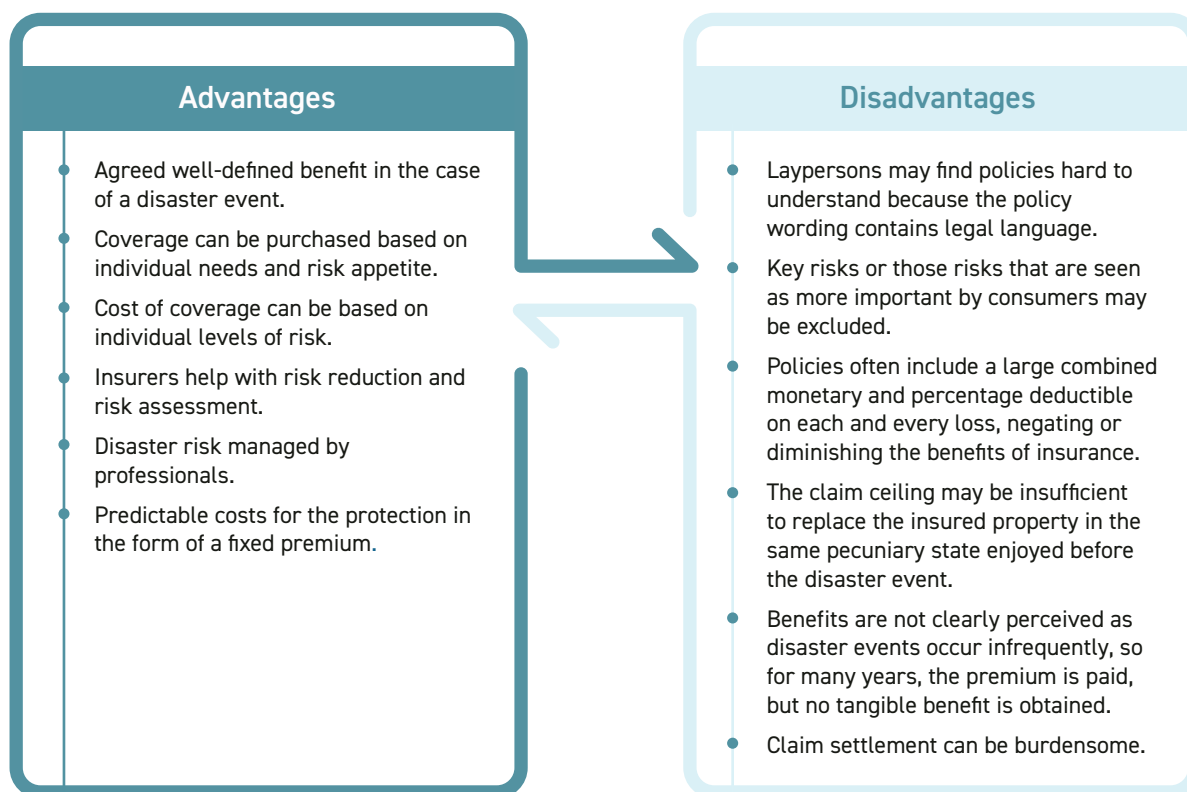
1 Disaster Insurance

Definition

Insurance is a financial transaction by which the insured, a physical or legal person, transfers to an insurer their natural hazard risk in exchange for a payment (insurance premium). Insurance providers are licensed and supervised insurance companies, captive insurers, and insurance pools, entities exclusively dedicated to 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 entails 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, so the transfer of the risk through insurance is appealing as a valid risk management strategy.



³⁵ Asian Development Bank (ADB). Assessing the Enabling Environment for Disaster Risk Financing – A Country Diagnostics Tool Kit. Manila, 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 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 crowding out 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.

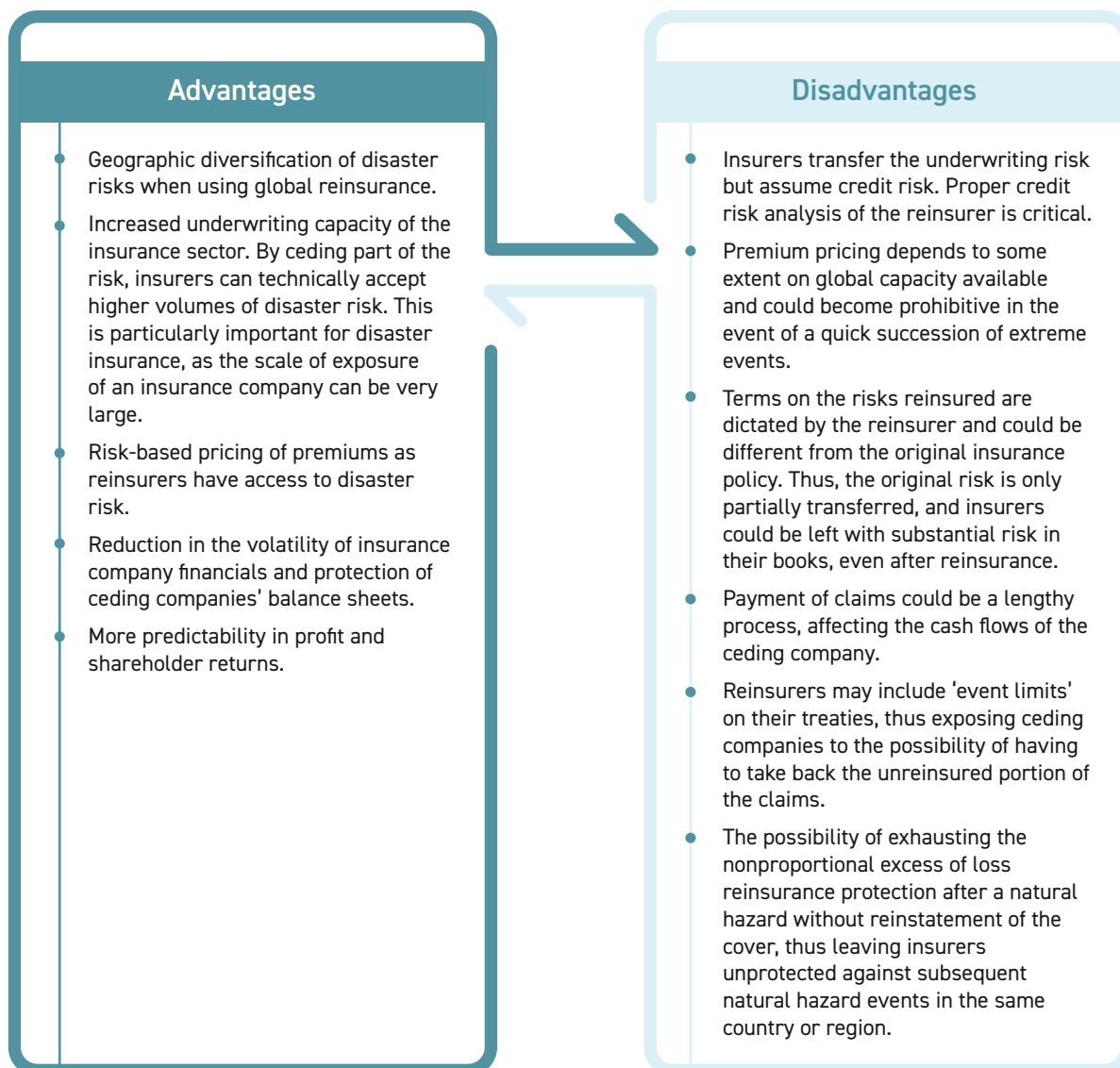
2 Disaster Reinsurance

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 can also participate in reinsurance (Wehrhahn 2009). Reinsurers can effectively assume huge amounts of disaster risk because they diversify by accepting risks from around the world and maintain substantial amounts of capital to support the assumed risks.

Main usage

Major disaster risk entails 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 possibilities, insurers would not be in an economic position to accept this type of risk on their own. Insurers assuming disaster risk protect their balance sheet by entering into reinsurance agreements.



Preconditions

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

3 Insurance-Linked Securities

Definition

Insurance-linked securities (ILS) are investment instruments that transform insurance risk into transparent and tradable capital market products. Investors accept insurance risk in exchange for a higher rate of return as compared with other securities that are free of that risk. The insurance risk materializes if a predefined disaster event occurs, such as an earthquake or tropical cyclone of a certain intensity. ILS includes categories like 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 to provide (re)insurance coverage for 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 sits 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 verified.
- 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 shortage of retrocession capacity or complex pricing cycles in traditional reinsurance markets.
- Multiyear pricing stability (terms of three to five 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 including the triggers related to the underwriting risks adds complexity to the structure of the instrument.
- Costs may be relatively high if the volume of issuance is small. Transaction size varies from a minimum of around US\$100 million to US\$750 million or US\$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 can 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, among others.
- 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 referred to as 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., 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 whole farm.

5

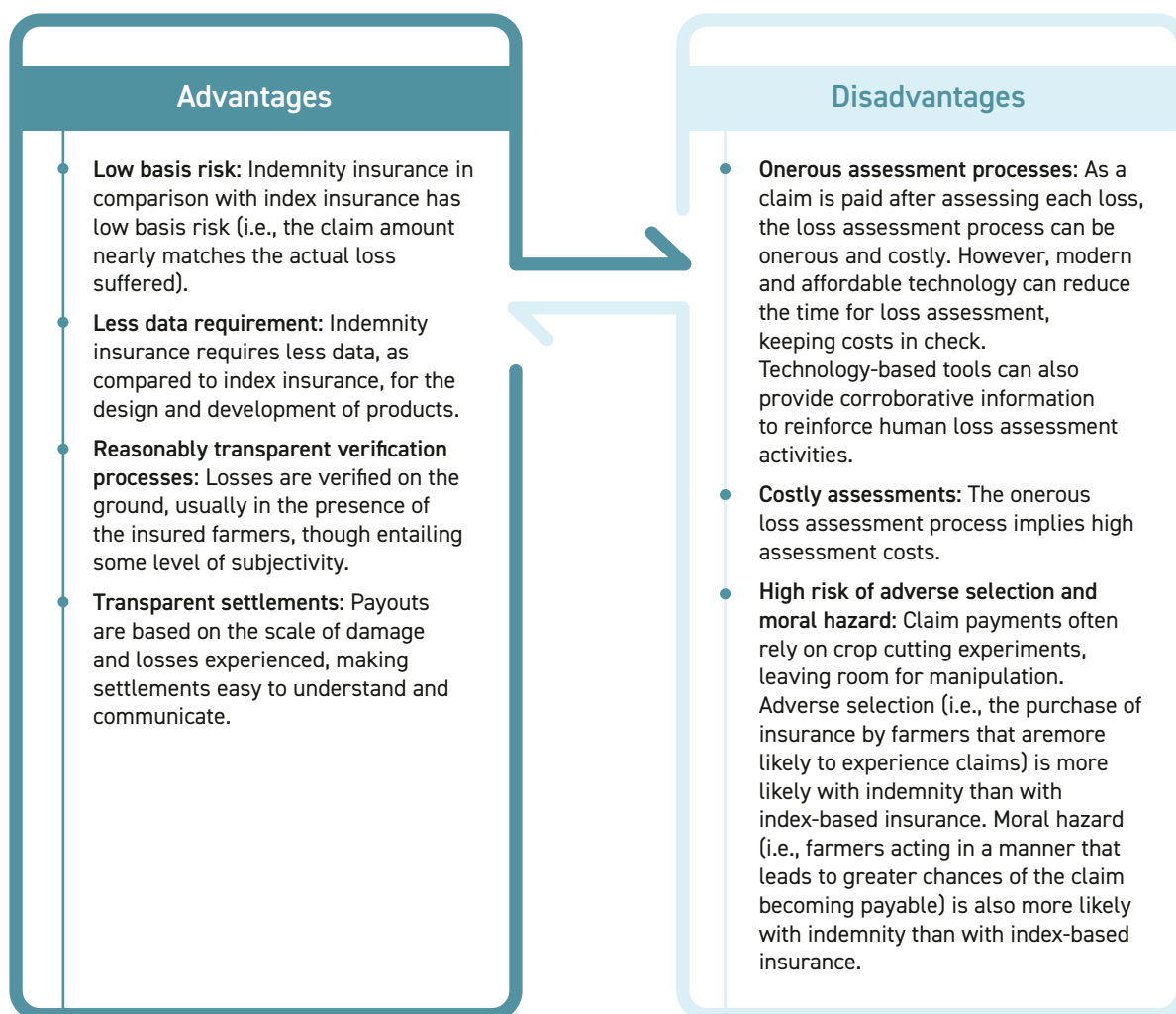
Farm-income protection insurance: Covers losses to future income (e.g., future droughts) based on investments in long-term production thereby reducing reliance on government assistance in times of need and building farmers' business resilience. It includes yields and price risks and also considers the costs of production. 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 of the guarantees, it can be whole-farm yield, revenue, or income insurance (EU 2008).

Main usage

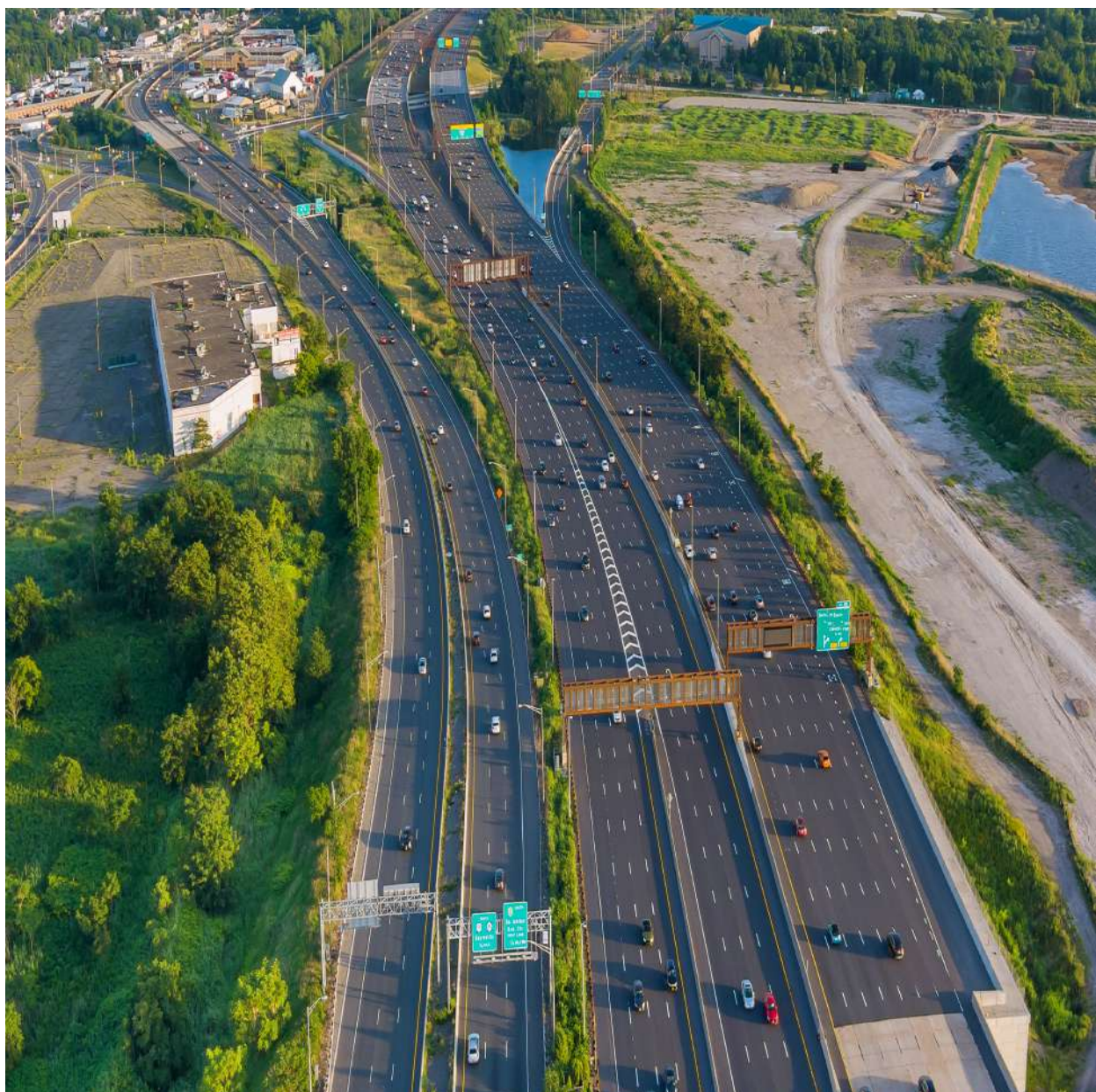
Agricultural indemnity insurance provides coverage to farmers and agricultural lenders against the loss of crop or livestock. When purchased by agricultural lenders, it can also increase their risk appetite to lend to farmers who are not otherwise creditworthy and at better terms than uninsured risks.



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 higher values, but the product needs to be designed such that the risks with higher frequency and lower values are not transferred to the insurer but instead retained – and hopefully reduced – through risk reduction efforts of the farmer.
- **Subject specialists:** Worthy products are usually developed with assistance from subject specialists. It is, therefore, important to make sure that the product development team has access to the required types of 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. It is possible that 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 into the main business activities of the insured persons.

- **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 lead to large and often covariate losses for the insurer and higher demands on capital 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 becomes necessary for agricultural insurance, which inherently faces large and 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

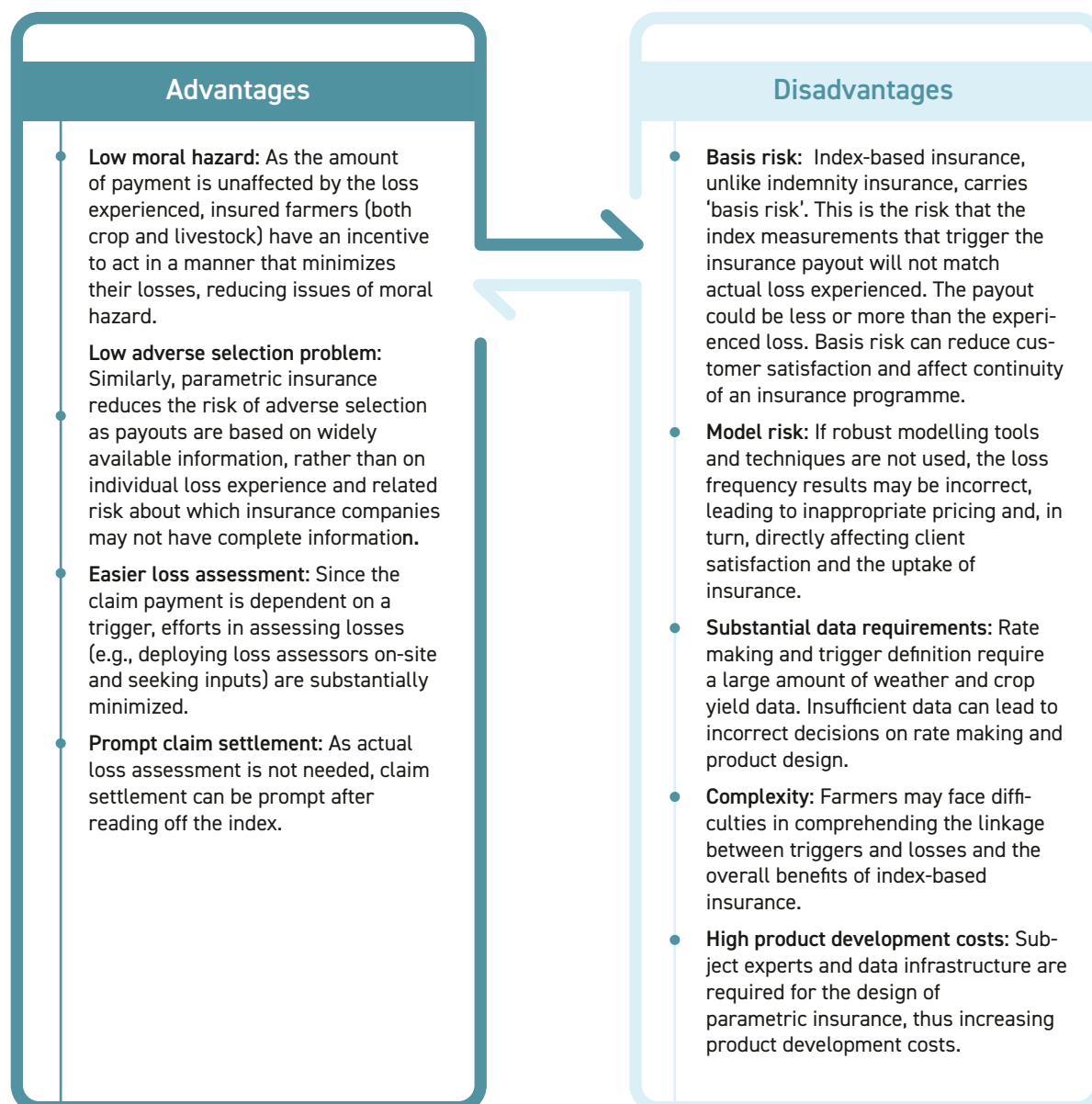
Agricultural parametric insurance is a form of insurance that *ex ante* agrees to make a payment upon the occurrence of a trigger observation or event linked to the loss, rather than indemnifying the pure agricultural loss (i.e., crop or livestock). The trigger observation could be a decrease in average 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 on parameters that most likely have multiple outcomes (wind velocity, precipitation levels, etc.) 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 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 to farmers and agricultural lenders by eliminating the element of subjectivity in loss verification and reducing the time to settle claims. When purchased by agricultural lenders, it can also increase their appetite to lend to farmers who are not otherwise creditworthy and to lend on better terms for farmers.



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 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.



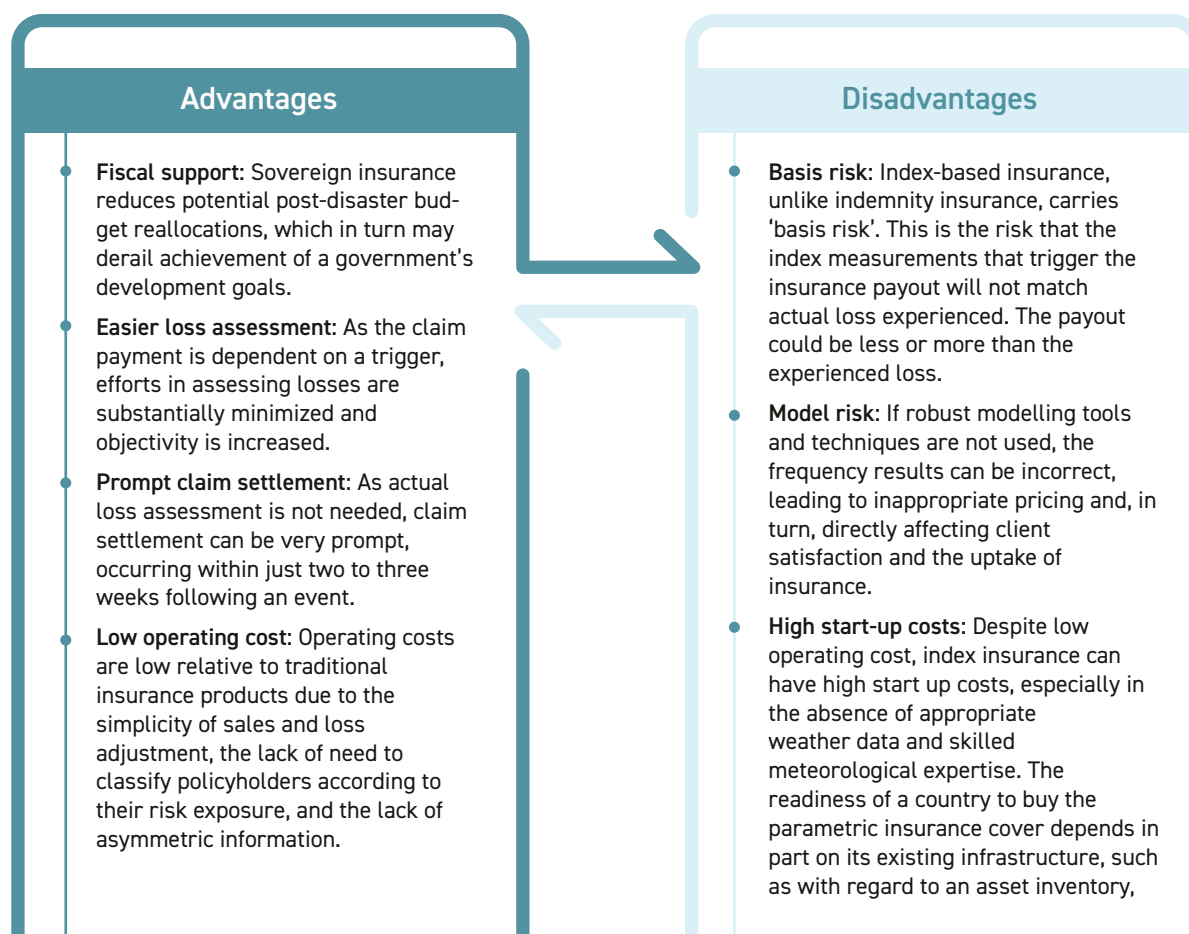
6 Sovereign Parametric Insurance

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. The trigger observations can be specified intensities of natural hazards in a specified location (e.g., rainfall level, wind speed, seismic shocks as measured on a 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.



- **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.

meteorological data, 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 make sure that 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 give rise to gaps in coverage 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.

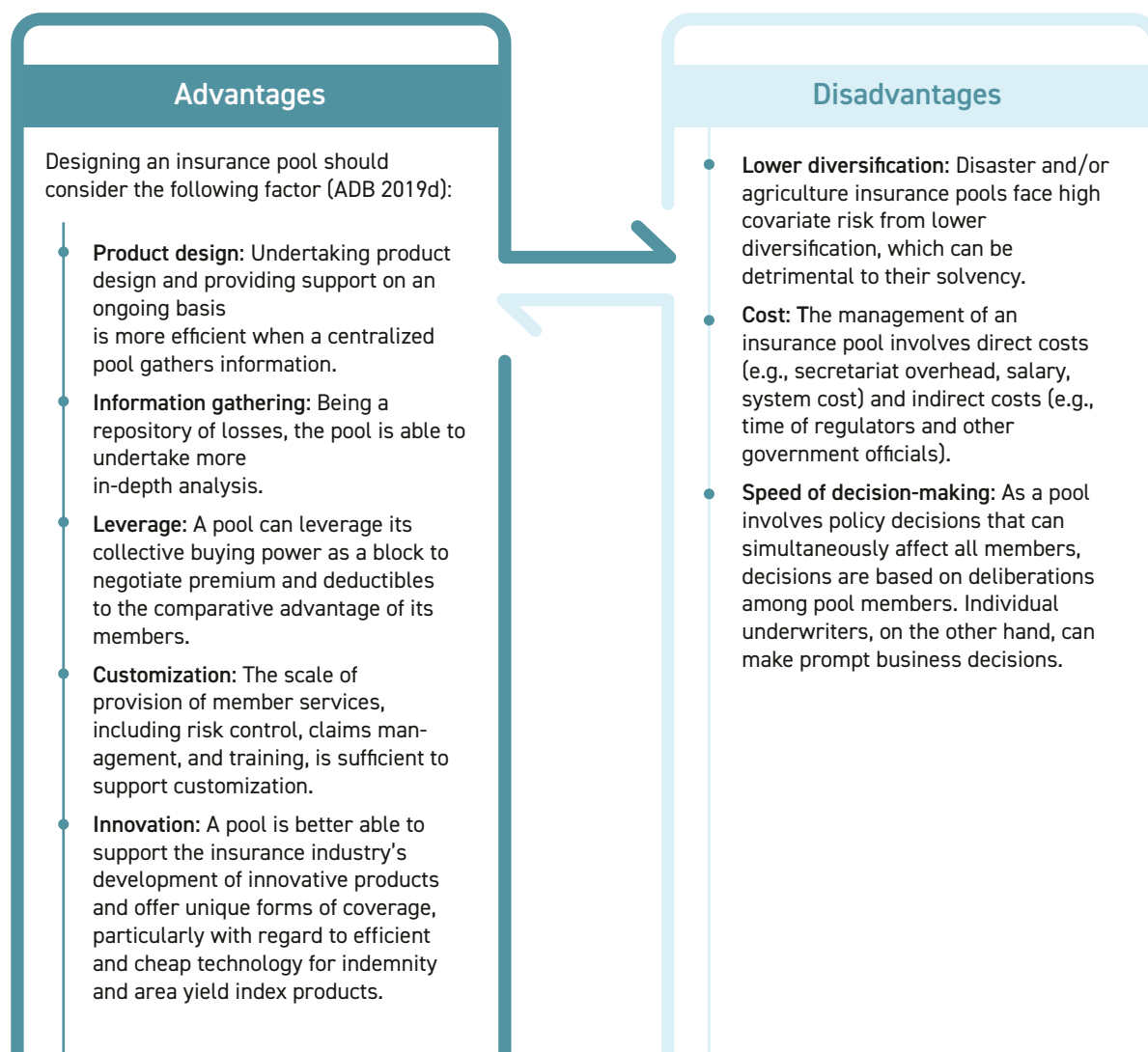
7 Insurance Pool

Definition

An insurance pool is a multiple-member risk-sharing arrangement where organizations (often primary underwriters) pool their funds together to finance an 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.



- **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 in supplying 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 proper reinsurance arrangements to maintain the solvency of the pool.
- **Regulatory framework:** Insurance pools involve many stakeholders and underwrite large, collective risks. In order to prevent conflict, it is necessary to have rules or regulations in place to demarcate the rights and duties of all the stakeholders.
- **Subject experts:** Managing a pool's risks and information keeping requires subject specialists. Often, it requires involving subject specialists who have a strong understanding of the specific risks being pooled, as well as an in-depth understanding 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 term (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 after certain performance parameters have been achieved.
- **Information systems:** Adequate information technology systems are needed to record data, settle distribution costs and claims, and demonstrate solvency.

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