

Mainstreaming Disaster Resilience into Infrastructure Projects

Insights from Infrastructure Sectors in India

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Mainstreaming Disaster Resilience into Infrastructure Projects

Insights from Infrastructure Sectors in India

This report provides an overview of all activities conducted under the study "Mainstreaming Disaster Resilience into Infrastructure Projects." The study's outputs will be provided as embedded documents along with this report.

This includes:

1. Resilience Cost-Benefit Analysis (RCBA) tool

2. Toolkit for integrating Disaster Resilience includes

i. List of resilience measures

List 1: Resilience measures for bidding and contractual documents

List 2: Design options for asset resilience

ii. Guidance documents for line ministries and potential bidders

Guidance Document 1:

Project identification and appraisal guidance document for line ministries to include disaster risk considerations

Guidance Document 2:

Project proposal preparation guidance document for potential bidders to include disaster resilience goals

Foreword

The increasing frequency and intensity of weather- and climate-related events pose significant challenges to infrastructure and economic stability. As these natural hazards threaten our infrastructure investments, we must shift our focus towards incorporating disaster resilience into the very fabric of our infrastructure development strategies. This proactive approach not only safeguards our assets but also ensures sustained economic growth by mitigating the impacts of future disasters.

An essential component of achieving this vision is to incorporate the resilience of assets in the infrastructure policy, infrastructure financing and infrastructure development framework. There shall be a policy framework to push resilience into project structuring. The feasibility of resilient infrastructure needs to be ascertained and the cost of resilient infrastructure needs to be identified and supported.

There is a growing awareness in the Government of India regarding these aspects. Several initiatives have been launched to address disaster impacts and to manage associated risks; and the Coalition for Disaster Resilient Infrastructure (CDRI) is a flagship initiative dedicated to enhancing infrastructure resilience nationwide. The collaboration between the CDRI and the DEA underscores our commitment to transform the development of infrastructure. This study by the CDRI titled “Mainstreaming Disaster Resilience into Infrastructure Projects: Insights from Infrastructure sectors in India” is one among such initiatives.

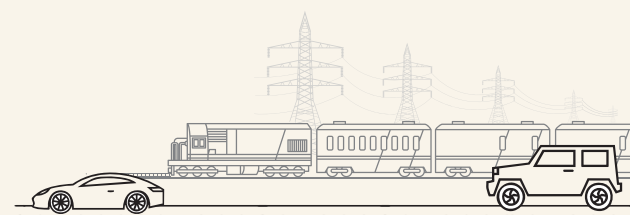
This study emphasizes the importance of integrating disaster resilience in the earliest stages of infrastructure projects. By focusing on three sectors of infrastructure with significant investments and importance (roads, railways and power), the study includes a comprehensive analysis of existing standard agreements and contractual documents and offers actionable recommendations to embed resilience. It will not only help in mainstreaming disaster resilience and protect investments, but also enhance the safety and well-being of our communities. This study will serve as a pivotal resource for policymakers, developers and stakeholders, guiding them towards creating infrastructure that is not only robust and reliable but also sustainable and forward-looking.

I extend my gratitude to CDRI and all contributors to this study for their efforts, expertise and commitment. I am hopeful that it will pave the way for a resilient future where infrastructure stands as a pillar of strength against the uncertainties of natural hazards.

Shri Baldeo Purushartha

Joint Secretary

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Preface

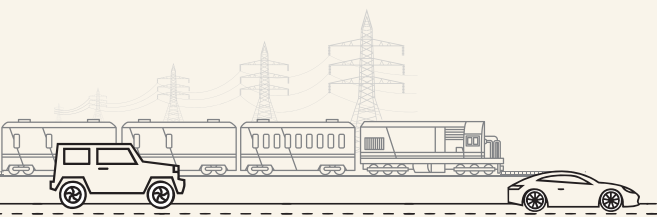
The Coalition for Disaster Resilient Infrastructure (CDRI) is pleased to present this study which aims to support policymakers, infrastructure developers and financiers in systematically integrating disaster risk considerations throughout the entire infrastructure lifecycle.

Projected infrastructure investments stood at US\$¹1.5 trillion for FY 2020–2025. As of FY 2026, this projection has been revised upwards to \$2.3 trillion. As infrastructure development accelerates—including in areas vulnerable to natural hazards—the risk of disaster-related losses that can undermine growth and reverse development gains becomes increasingly pronounced.

Recognizing this challenge, the Department of Economic Affairs (DEA), Ministry of Finance (MoF), Government of India, requested CDRI to undertake this study. The objective was to examine current contractual frameworks and identify entry points for embedding disaster resilience measures. The study also evaluates the cost-effectiveness of such interventions through pilot cost-benefit analyses of selected projects. In collaboration with infrastructure line ministries, including Roads, Power and Railways, we reviewed key contractual documents such as Detailed Project Reports (DPRs), Standard Bidding Documents (SBDs) and Model Concessionaire Agreements (MCAs) relevant to both public sector and Public-Private Partnership (PPP) projects. With guidance from the DEA's Infrastructure Division, we selected representative projects across sectors—including power transmission and distribution lines, road networks and a railway corridor—to assess their disaster vulnerability using hazard exposure and vulnerability frameworks. Historical data informed these assessments on natural hazard events in the respective project areas.

To identify actionable resilience interventions, we analyzed the DPRs, drew on global best practices from countries such as the United Kingdom, Australia, the USA and Japan, and evaluated the potential benefits of these measures by estimating avoided damages and revenue losses under both business-as-usual and resilience-enhanced scenarios. The findings underscore a compelling economic case for resilience, with returns on investment reaching up to 12:1 in some instances.

India's plan to become a developed economy by 2047, with a projected GDP of \$30 trillion, relies heavily on sustained and inclusive growth. Embedding disaster resilience into infrastructure development is not just a risk mitigation strategy; it is a foundational investment in the country's long-term growth and stability.



Amit Prothi
Director General

Coalition for Disaster Resilient Infrastructure

¹All figures denoted by "\$" represent US dollars, unless otherwise indicated.

Acknowledgement

The Coalition for Disaster Resilient Infrastructure (CDRI) is deeply grateful to all individuals and organizations whose contributions were instrumental in the completion of this study.

Appreciation is extended to the team from the DEA for facilitating consultations, data collection and coordination with the line ministries, as well as to representatives from Ministry of Road Transport and Highways, National Highways and Infrastructure Development Corporation Limited, Ministry of Railways, Ministry of Power, Power Grid Corporation of India Limited and Central Electricity Authority for providing invaluable insights and feedback throughout the study.

CDRI acknowledges the encouragement, guidance, feedback and contributions of technical experts from the Appraisal and Steering Committee (ASC) and the participants in panel discussions and roundtable conferences where the study was presented and discussed.

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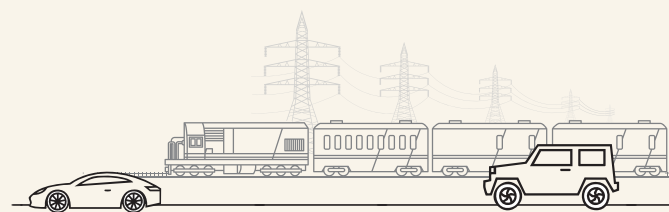


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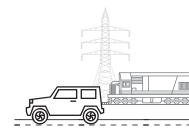
Abbreviations

AAL	Average Annual Loss	IRIF	India Risk Insurance Facility
ADB	Asian Development Bank	IRR	Internal Rate of Return
ARC	African Risk Capacity	ISTS	Inter-State Transmission System
BBB	Building Back Better	JICA	Japan International Cooperation Agency
BCR	Benefit-Cost Ratio	MCA	Model Concessional Agreements
BIM	Building Information Modelling	MDBs	Multilateral Development Banks
BIS	Bureau of Indian Standards	NAIF	North Australia Infrastructure Facility
CBA	Cost-Benefit Analysis	NDEM	National Database for Emergency Management
CBRT	Climate Bonds Resilience Taxonomy	NDMA	National Disaster Management Authority
CCA	Climate Change Adaptation	NDMF	National Disaster Mitigation Fund
CCRIF	Caribbean Catastrophe Risk Insurance Facility	NDRMF	National Disaster Risk Management Fund
CDRI	Coalition for Disaster Resilient Infrastructure	NHIDCL	National Highways and Infrastructure Development Corporation Limited
CEA	Central Electricity Authority	NIDM	National Institute of Disaster Management
DCA	Draft Concession Agreement	NIIF	National Investment and Infrastructure Fund
DEA	Department of Economic Affairs	NIP	National Infrastructure Pipeline
DFIs	Development Finance Institutions	NMSHE	National Mission for Sustaining the Himalayan Ecosystem
DLP	Defect Liability Period	NMSKCC	National Mission on Strategic Knowledge for Climate Change
DPR	Detailed Project Report	NPV	Net Present Value
DRF	Disaster Risk Financing	NSDI	National Spatial Data Infrastructure
DRFI	Disaster Risk Financing and Insurance	O&M	Operations and Maintenance
DRR	Disaster Risk Reduction	PCDIP	Philippine City Disaster Insurance Pool
DSS	Decision Support System	PCRAM	Physical Climate Risk Assessment Methodology
DST	Department of Science and Technology	PGCIL	Power Grid Corporation of India Limited
EIA	Environmental Impact Assessment	PMGSY	Pradhan Mantri Gram Sadak Yojana
EPC	Engineering, Procurement and Construction	PPP	Public-Private Partnerships
GAR	Global Assessment Report	RCBA	Resilience Cost-Benefit Analysis
GFDRR	Global Facility for Disaster Reduction and Recovery	RDSO	Research Designs and Standards Organization
GGEF	Green Growth Equity Fund	RFP	Requests for Proposals
GIRI	Global Infrastructure Risk Model and Resilience Index	RoI	Return on Investment
GIS	Geographic Information System	RVNL	Rail Vikas Nigam Limited
GRAF	Global Risk Assessment Framework	SBD	Standard Bidding Documents
HAM	Hybrid Annuity Model	SEADRIF	Southeast Asia Disaster Risk Insurance Facility
ICDRI	International Conference on Disaster Resilient Infrastructure	SoPs	Standard Operating Procedures
IDB	Inter-American Development Bank	TBCB	Tariff-Based Competitive Bidding
IE	Independent Engineer	TSA	Transmission Service Agreement
IEA	International Energy Agency	TSP	Transmission Service Provider
IIRF	India Infrastructure Resilience Fund	UNDRR	United Nations Office for Disaster Risk Reduction
IMD	Indian Meteorological Department	VGF	Viability Gap Funding
IPMD	Infrastructure and Project Monitoring Division	WB	World Bank
IRC	Indian Road Congress		
IRDAI	Insurance Regulatory and Development Authority of India		



1

Introduction and Current Landscape



1 Introduction and Current Landscape

1.1 Background

India will need to spend \$4.51 trillion on infrastructure by 2030 to realise the vision of a \$5 trillion economy (Taskforce Report, Department of Economic Affairs (DEA), Government of India (GOI), and the GOI aims to facilitate this efficiently. However considering the growing risks of natural hazards and climate change, DEA has incorporated a strategic goal to ensure that public infrastructure is designed, constructed, and maintained in alignment with resilience goals.

Impact of Hazards

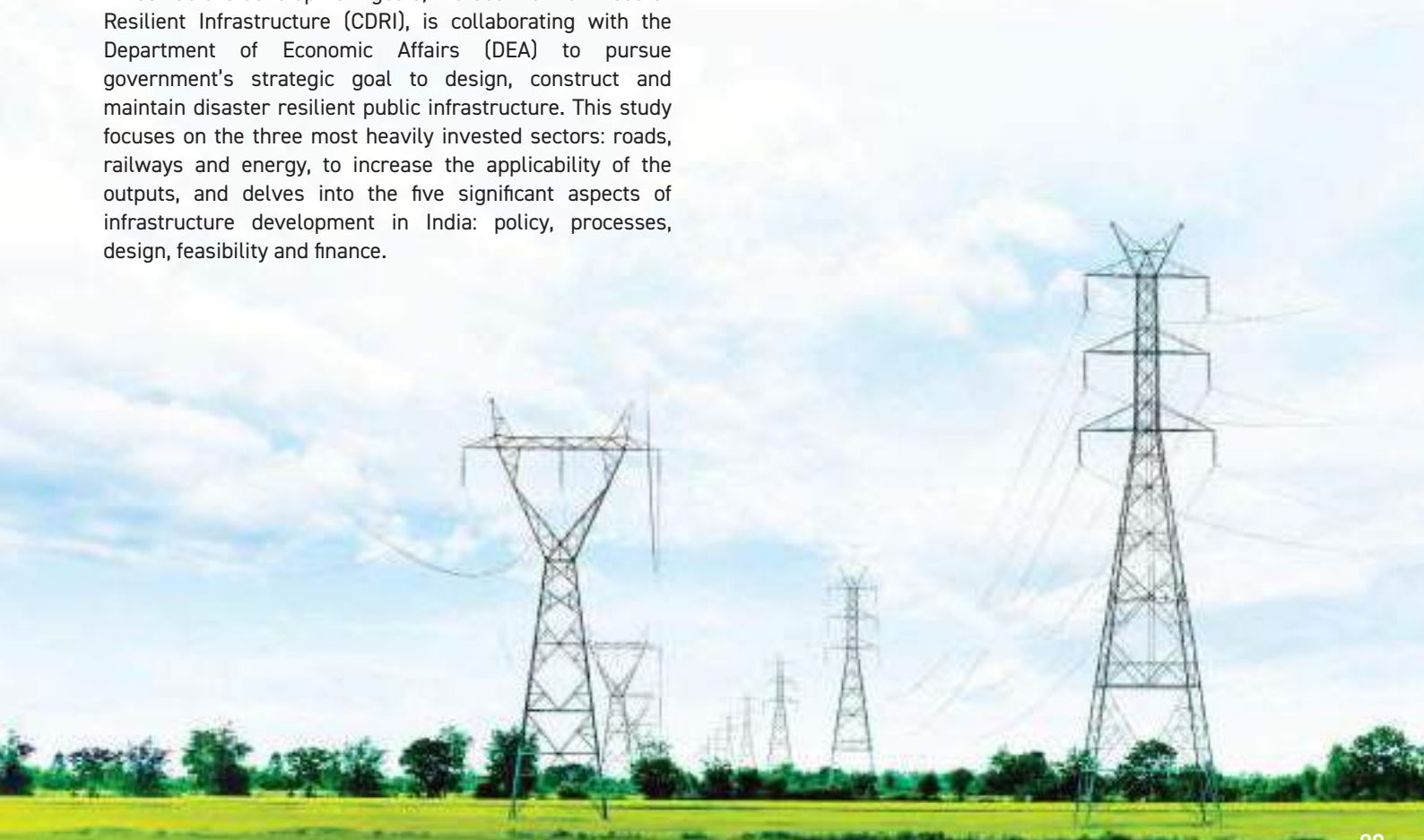
Natural hazards pose a direct threat to Infrastructure assets globally and in India. Approximately \$18 billion worth of direct damage to power generation and transportation infrastructure was reported in low- and middle-income countries. (WB, 2019). India too has suffered considerable infrastructure damage due to weather and climate-related events, with estimated investment losses ranging from \$619 billion to \$1.02 trillion (INR 46 to 73 lakh crore). As natural hazards increasingly threaten infrastructure investments, incorporating disaster resilience in infrastructure provides economic benefits by reducing future disaster impacts on assets.

To address existing disaster risks while achieving the infrastructure development goals, the Coalition for Disaster Resilient Infrastructure (CDRI), is collaborating with the Department of Economic Affairs (DEA) to pursue government's strategic goal to design, construct and maintain disaster resilient public infrastructure. This study focuses on the three most heavily invested sectors: roads, railways and energy, to increase the applicability of the outputs, and delves into the five significant aspects of infrastructure development in India: policy, processes, design, feasibility and finance.

The identified gaps are addressed through the study's outputs, which include recommendations, a tool and a toolkit. The Resilience Cost-Benefit Analysis (RCBA) tool aids in design feasibility and bridges financing gaps by justifying the upfront cost of investing. The Toolkit for Disaster Resilience helps incorporate resilience practices within standard processes and procurement documents used for implementing infrastructure projects in India. Together, they aim to assist the government and line ministries in addressing disaster risks by mainstreaming resilience considerations into their policies and programmes.

Objective

Disaster resilient infrastructure is designed to withstand and quickly recover from disasters, ensuring continuity of essential services and minimising economic losses. Investing in resilience supports long-term economic growth and continuity of the systems. The objective of the study is to integrate disaster resilience throughout the infrastructure project lifecycle by providing tools and toolkits to assist the government and implementing agencies.



1.2 About the study

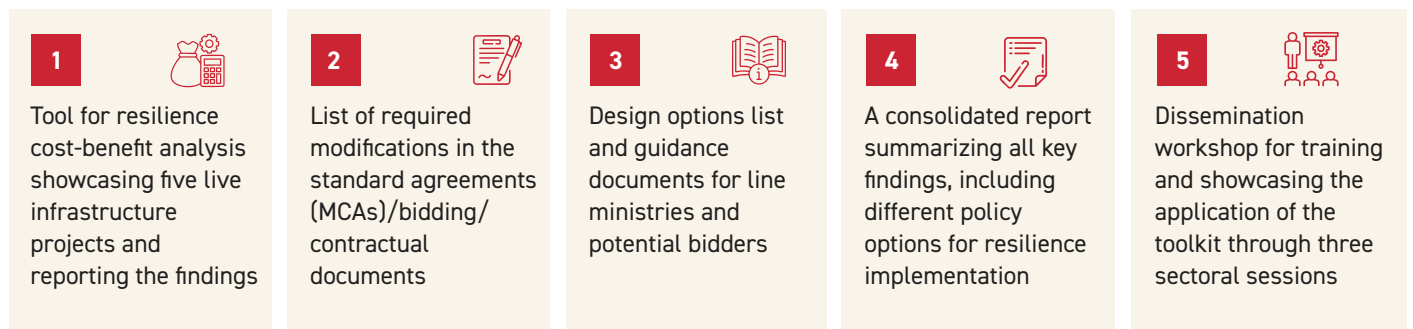
The scope of the project includes the following:

- Develop a **Resilience Cost-Benefit Analysis (RCBA) tool** and test it on five sample NIP projects across three sectors (Roads, Power and Railways).
- Conduct an appraisal of standard contractual documents, including model concessionaire agreements and standard

bidding documents related to public-private partnerships (PPPs) and engineering, procurement and construction (EPC) modes of implementation.

- Develop a **toolkit** for line ministries and potential bidders to guide disaster resilient infrastructure investments.

Project outputs:



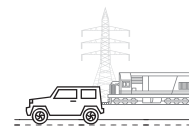
1.3 Approach

The study's approach included a literature review of global critical infrastructure resilience practices, as well as stakeholder consultations, workshops and appraisals of standard bidding documents for the roads, railways and power sectors. Having identified gaps across five key areas—Standard Contracts, Project lifecycle, Data & Risk Assessment Systems, Capacities, and Financing—a list of recommendations has been provided to help strengthen disaster resilience considerations within the infrastructure

sector. Additionally, two outputs were developed: a) a resilience cost-benefit analysis (RCBA) tool to justify investing in resilience and b) a toolkit for infrastructure resilience to incorporate resilience considerations in infrastructure projects. The RCBA tool and toolkit will help relevant stakeholders, including line ministries, implementing agencies, technical bodies and private players, bring the recommendations to action.



Figure 1: Approach for conducting the study



Limitations of the study

The RCBA tool does not cover climate change scenarios and does not accurately determine future impact costs, as it relies on past hazard and vulnerability data from various sources.

The RCBA tool's assessment and is limited to financial benefits from resilience measures in terms of damages avoided and revenue losses to projects due to disruptions if any (does not consider economic benefits). Further, the

project appraises only one model concessionaire agreement or standard bidding document approved by the Government of India in each of the three predominant sectors, focusing solely on parts relevant to resilience interventions. Additionally, consistent natural hazard mapping is unavailable across India, and resilience clauses in standard documents require further development by legal experts and key stakeholders.

Structure of the report

Chapter 1

Introduction and Current Landscape

This chapter provides the background of the study. It outlines the study's objectives, scope, outputs and limitations, and highlights the need for resilience through analysis of national and global practices. The chapter also identifies five key gaps in the Infrastructure Resilience Ecosystem.

Chapter 2

Recommendations for Mainstreaming Disaster Resilience

This chapter provides a list of recommendations to address the identified five key gap areas. The chapter also summarizes the recommendations based on short-term, medium-term and long-term applicability and indicates the priority tasks to bring the recommendations to action.

Chapter 3

Resilience Cost-Benefit Analysis Tool

This chapter provides details on the RCBA tool, including its objectives, stakeholder benefits, target users, applicability, scope and outputs.

Chapter 4

Toolkit for Infrastructure Resilience

This chapter provides details on the toolkit for infrastructure resilience. It discusses its purpose, key features, users and applicability.



1.4 Overview of the global landscape and need analysis

Globally, over the last 50 years, the frequency of disasters has increased by a factor of five due to climate change and extreme weather events. (WMO, 2021). Data indicates there is an upward trend in annual disaster events from 1980 to 2013 (MunichRE, 2014) (see Fig. 2). As these events become more frequent, the vulnerabilities and risks associated with hazards have also escalated. Natural hazards, such as floods, cyclones, earthquakes and landslides, pose significant

threats to critical infrastructure, disrupting socio-economic activities. These hazards cause both direct and indirect losses – direct losses include fatalities and damage to infrastructure, while indirect losses involve operational disruptions and revenue declines. Therefore, robustness and reliability of critical infrastructure are essential for societal stability and economic vitality.

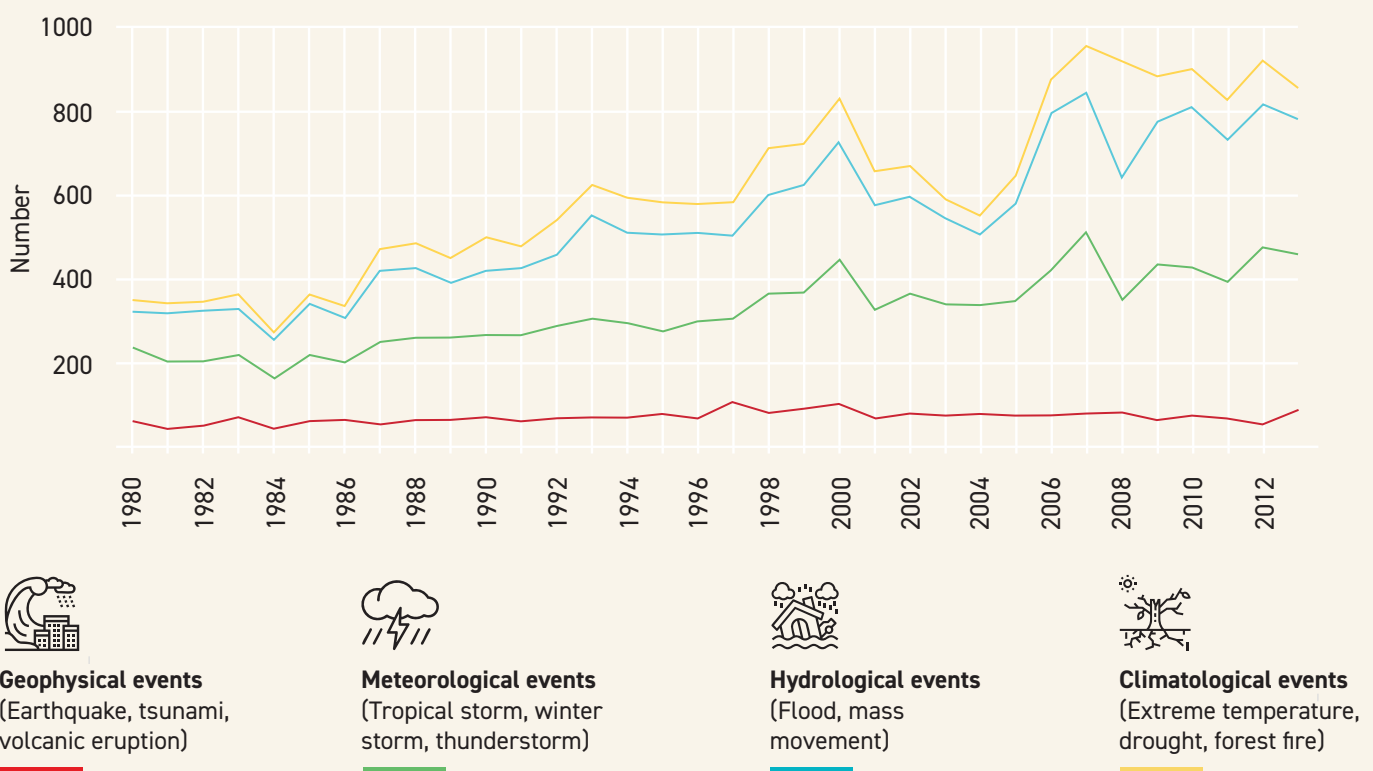
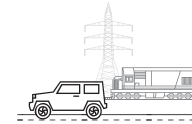


Figure 2: Annual number of disasters associated with natural events around the world from 1980 to 2013

(Source: NatCatSERVICE, Munich Re, 2014)

India's vast and varied geography makes it prone to various types of natural hazards, including earthquakes, floods, cyclones, droughts and landslides. India's critical infrastructure, including power, roads, irrigation and public buildings, accounted for nearly 50 percent of direct losses during Cyclone Fani in 2019 and the 2018 Kerala floods. Global data suggests that up to 66 percent of public sector losses occurring from weather- and climate-related events are due to infrastructure damage (NIDM, 2019). Addressing the risks associated with such impacts is crucial for developing resilient infrastructure. Figure 3 shows the degree of influence of natural hazards on various infrastructure asset classes.

The (NIP) has witnessed significant investments across various sectors, with concentrated allocations in the power (24%), roads (18%) and railways (12%) sectors. Within these three sectors, roads and bridges (39%) are the most susceptible to natural hazards, followed closely by railway tracks (33%), transmission lines and substations (28%) (see Figure 4). When categorizing the loss data based on the various types of natural hazards, floods in the power sector alone contribute to an average annual loss (AAL) of approximately \$86.21 million, followed by cyclonic winds and earthquakes (see Figure 5). In the railways sector, floods and earthquakes are major causes of significant losses (see Figure 6). Similarly, in the roads sector, floods alone can result in an AAL of \$172.31 million (see Figure 7).



Sectors	Earthquake	Cyclone	Flood	Tsunami	Wildfire	Extreme Heat
Roads	●	●	●	●	●	●
Energy	●	●	●	●	●	●
Railway	●	●	●	●	●	●
Real Estate	●	●	●	●	●	●
Urban Public Transport	●	●	●	●	●	●
Healthcare	●	●	●	●	●	●
Telecommunication	●	●	●	●	●	●

Degree of Impact

●	●	●	●
Very High	High	Medium	Low

Figure 3: Impact of natural hazards on critical infrastructure asset classes
 Source: Adapted from Dawson (2015) as cited in OECD (2017) and McKinsey (2019).

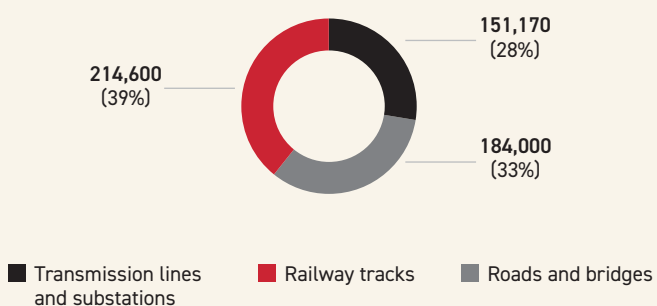


Figure 4: Exposure of most invested critical infrastructure sectors in India in \$ million (GIRI portal 2023)

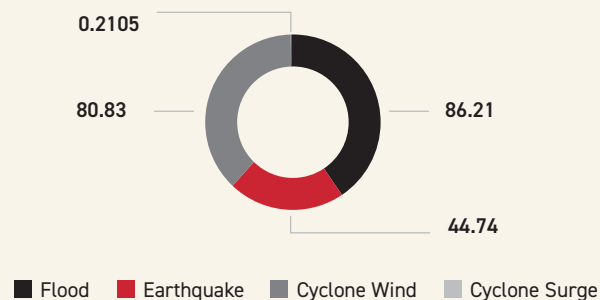


Figure 5: AAL in transportation assets of India due to hazards in \$ million (GIRI portal 2023)

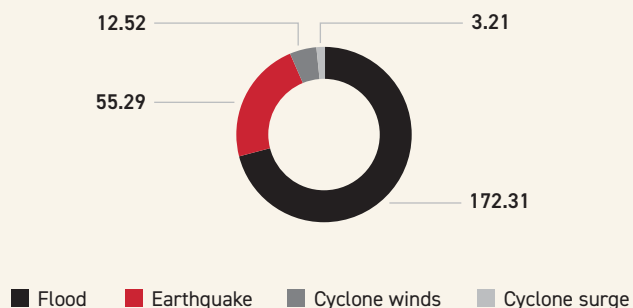


Figure 6: AAL in railways assets of India due to hazards in \$ million (GIRI portal 2023)

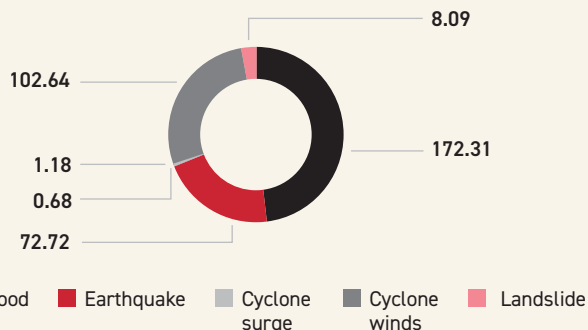


Figure 7: AAL in road assets of India due to hazards in \$ million (GIRI portal 2023)

With a total investment of \$2.34 trillion as of April 2025, there is a significant benefit from integrating resilience throughout the project phases, especially at development or conceptual stages as while resilience measures entail additional costs, they secure assets from long-term disaster risks.

1.4.1 Insights from existing resilience frameworks and global practices

To advance the government's efforts in mainstreaming infrastructure resilience, it is useful to understand the global and national approaches, gain insights into the current state of infrastructure resilience and identify key challenges. A comprehensive literature review and extensive consultations with relevant stakeholders have been conducted to identify critical gaps and opportunities for integrating resilience into infrastructure planning and development. Resilience frameworks and methodologies from organizations such as the World Bank, Asian Development Bank and ARUP have been reviewed for their applicability across various project stages and hazards. These frameworks, from planning to maintenance, address system interdependencies and enhance infrastructure resilience by understanding hazards, vulnerabilities and risks, incorporating principles of redundancy, robustness and adaptability.

Frameworks like the **Resilience Measurement Index** and the **Critical Infrastructure Resilience Index** utilize multi-level indicators to assess resilience, encompassing assets,

services and users. ETH Zürich evaluates resilience through pre- and post-event indicators, while the GIRI Framework uses a multi-hazard probabilistic risk assessment to rank countries based on their expected AAL. The Physical Climate Risk Assessment Methodology (PCRAM), developed by the Coalition for Climate Resilient Investment (CCRI), integrates diverse inputs to assess climate risks in infrastructure investment and appraisal practices, promoting more resilient and sustainable outcomes. More details on the frameworks, along with key features and use cases, have been enclosed in Annexure 2.

The literature review identified global challenges faced by critical infrastructure due to natural hazards and highlighted specific responses by various countries each facing unique risks based on geography and infrastructure type. It explores strategies to enhance the resilience of infrastructure, such as power, roads and railways, through both structural and non-structural measures. Table 1 below presents the key learnings from international good practices on structural and non-structural resilience measures.

Table 1: Key learnings from international good practices on structural and non-structural resilience measures.

Measures	Key Learnings
Structural measures	
Design and construction standards	<ul style="list-style-type: none"> ■ Designing power systems useful in both normal and emergency situations maximize investment efficiency.
Retrofitting and upgrades	<ul style="list-style-type: none"> ■ Following the 'Building Back Better' concept focused on resilience-based reconstruction, integrated development approach and enhanced service quality ■ Upgrading infrastructure with modern technologies like improved traffic management and drainage systems helped bolster resilience, overall efficiency and safety
Redundancy and backup systems	<ul style="list-style-type: none"> ■ Developing a mini-grid system reduces reliance on a single power provider, ensuring continuous energy supply during outages
Innovative technologies	<ul style="list-style-type: none"> ■ Investing in innovative technologies like advanced metering infrastructure (AMI) helps enhance situational awareness, efficient resource allocation, improved grid resilience, operational efficiency and cost savings.
Non Structural Measures	
Policy and regulation	<ul style="list-style-type: none"> ■ Implementing strategies to reduce power flow in transmission lines can help manage congestion, prevent overloading and enhance the grid's stability. <p>Infrastructure Australia's guidelines ensure the development of robust and responsive infrastructure. A multifaceted strategy with strong governmental involvement is essential for infrastructure resilience.</p>
Emergency planning and management	<ul style="list-style-type: none"> ■ Using innovative models such as NISMODO to ensure long-term infrastructure planning ■ Stress-testing infrastructure systems against extreme and unlikely events
Data and monitoring systems	<ul style="list-style-type: none"> ■ Integrating big data from multiple sources for real-time detection and management of public transport issues, enhancing system resilience ■ Utilizing smartphone sensors in vehicles offers a cost-effective and efficient method for infrastructure monitoring ■ Utilizing a phasor management unit for fault identification provides real-time monitoring and situational awareness
Community and stakeholder management	<ul style="list-style-type: none"> ■ Engaging citizens through open-source and interactive platforms can significantly improve public infrastructure monitoring and maintenance. Such tools enhance transparency, accountability and community involvement, leading to more efficient and responsive public services.



The review also highlights promising practices from developed countries, including the incorporation of resilience clauses in standard agreements and contractual documents, as well as initiatives to build resilience guidelines and modify contracts for equitable risk allocation. Furthermore, global resilience frameworks emphasize key aspects such as

hazard data ecosystems, risk and resilience assessments, financial impacts of disasters and resilience throughout the project phase. These insights helped in identifying major components for mainstreaming resilience in infrastructure projects. A snapshot of global good practices for building infrastructure resilience is given in Figure 8.

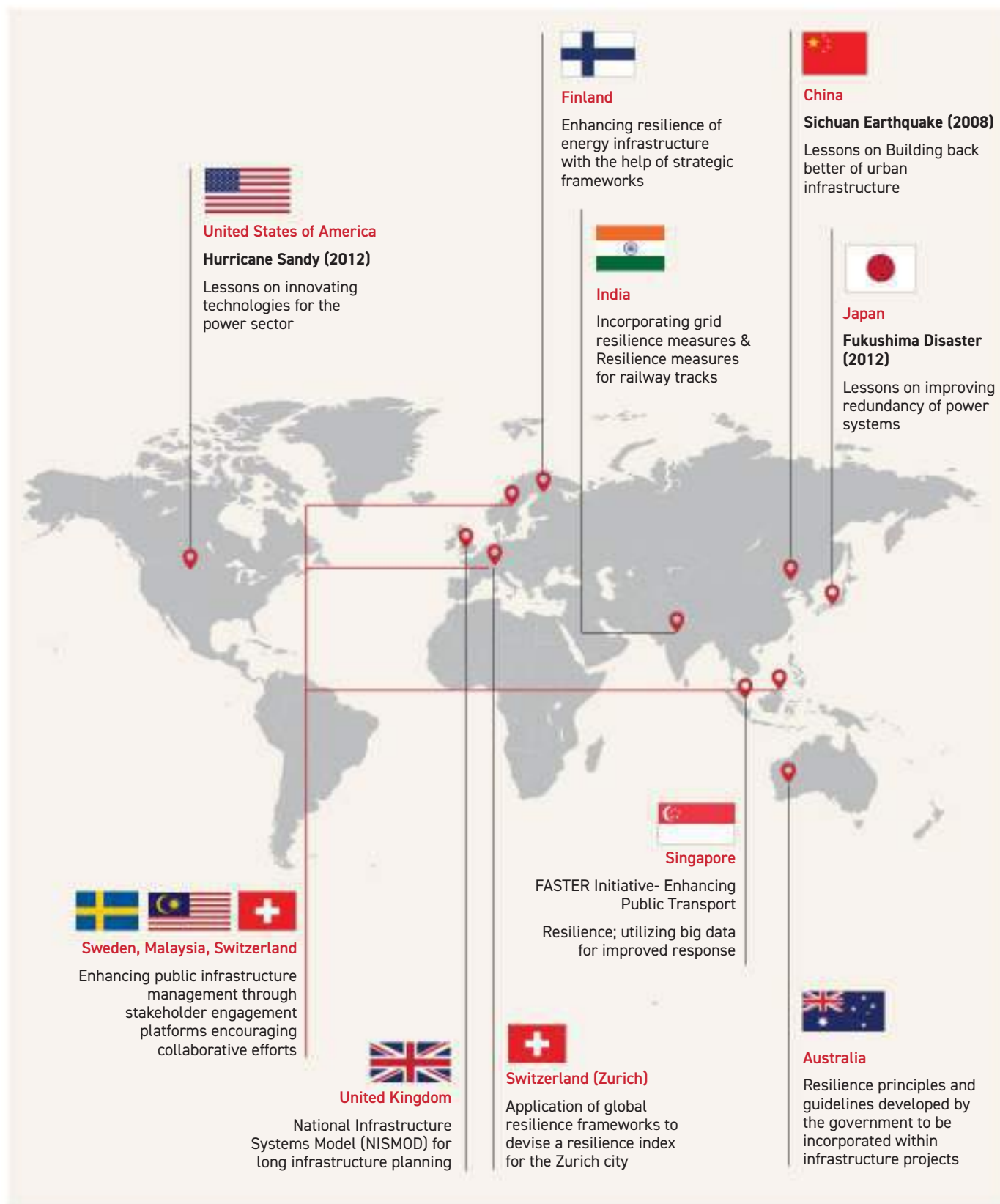


Figure 8: Some Global best practices: Structural and Non Structural Resilience measures

1.4.2 Insights from stakeholder consultations

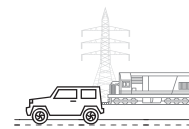
In addition to the literature review, one-on-one consultations, focused group discussions and workshops were conducted to gather insights from the stakeholders' extensive field experience (see Table 2).

Table 2: Key stakeholders and points of discussion

Key stakeholders		Key points of discussion
Line Ministries	Ministry of Road, Transport and Highways (MoRTH)	<ol style="list-style-type: none"> 1. Availability and location of standard bidding documents and model concessional agreements (MCAs) 2. Areas and types of assets impacted by natural hazards 3. Issues related to the current best practices on critical infrastructure resilience
	Ministry of Power	<ol style="list-style-type: none"> 4. Gaps within the existing resilient infrastructure development landscape 5. Information collection about live projects being implemented in hazard-prone regions
	Ministry of Finance	<ol style="list-style-type: none"> 1. Key sectors to be taken up for the study 2. Details regarding projects developed under NIP 3. Aspects to be covered under the RCBA tool 4. Applicability of the tool and toolkit across line ministries
Implementing Agencies	National Highways & Infrastructure Development Cooperation Limited (NHIDCL)	<ol style="list-style-type: none"> 1. Types of assets impacted by natural hazards 2. Current measures undertaken to strengthen infrastructure resilience 3. Existing gaps in contractual clauses and risk-sharing responsibilities
	Power Grid Corporation of India Limited (PGCIL)	
Technical Bodies	Central Electricity Authority (CEA)	<ol style="list-style-type: none"> 1. Types of assets significantly impacted by natural hazards 2. Current measures undertaken to strengthen infrastructure resilience 3. Existing gaps in contractual clauses and risk-sharing responsibilities 4. Best practices on material and design specifications 5. Information on relevant codes and standards
	Indian Road Congress (IRC)	<ol style="list-style-type: none"> 1. Regular update of codes and standards 2. Consideration of changing weather events in codes and standards
Others	National Disaster Management Authority (NDMA), 16th Finance Commission, Nippon Koei India, Sysra Consulting, Tata Consulting Engineering, The Blended Finance Company, Agence Francaise de Development (AFD), Foreign Commonwealth & Development Office, Canada Pension Plan Investment Board	<ol style="list-style-type: none"> 1. Streamlining of recommendations and way forward on DRF aspects 2. Increased fund allocation for mitigation through NDRMF 3. Ways to incentivize asset owners to incorporate resilience measures in asset design and construction 4. Recommendations for financing mechanisms like blended finance and concessional finance, as well as considering viability gap funding (VGF) and green bonds 5. Adoption of insurance products, such as cat bonds and parametric insurance, to enhance disaster resilience

These consultations highlighted several key insights for enhancing infrastructure resilience, including the integration of disaster resilience considerations from the planning phase, the necessity for comprehensive risk assessments, and the importance of strengthening the capacity of implementing and contracting agencies in developing Request for Proposals (RFPs). Discussions also emphasized

the potential of disaster risk transfer mechanisms and other project financing avenues, as well as the need for equitable disaster risk sharing in public-private partnership (PPP) and engineering, procurement and construction (EPC) contracts. Integrating resilience considerations in contractual clauses was deemed essential for achieving these goals (See Annexure 3).



1.4.3 Insights from appraisal of Standard Agreements and Contractual Documents

Policy and contractual obligations are essential for mainstreaming disaster resilience into infrastructure projects, as they establish the frameworks and ensure compliance throughout the project lifecycle. These obligations hold various stakeholders accountable for integrating resilience during the design and construction stages.

To ensure this, sector-specific standard agreements and contractual documents from the Government of India in the road, railway and power sectors were reviewed.

The appraisal was initiated by identifying the most prevalently used standard document from each sector. This was followed by identifying locations in the papers where resilience considerations need to be incorporated, and modifications were suggested in the articles and clauses to build resilience.

remedy, as well as damage rectification and suspension of work due to a lack of disaster resilience. There are no specific tests prescribed to ensure disaster resilience. Additionally, key stakeholder roles and responsibilities are unclear, which includes limiting the authority's right to modify work regarding safety and resilience measures. The power sector documents lack specific disaster resilience measures. For example, they do not outline transmission service provider (TSP) obligations specifically towards disaster resilience measures and lack details on who will validate or approve the TSP designs. Although an independent engineer (IE) is assigned to monitor these activities, there is no reference to any disaster resilient measures or features that need to be complied with.

Furthermore, international best practices were also studied and key learnings identified.

International best practices:

The G20 has emphasised the importance of incorporating low-cost resilience measures and clauses into concessionaire agreements to mitigate disaster-related losses. Countries like the USA and Australia are addressing financial liabilities from disasters, while in the Asia-Pacific region, resilience clauses are increasingly being incorporated into PPP contracts and procurement documents.

International approaches to critical infrastructure resilience in PPP emphasise sustainability, climate adaptation and transparent risk allocation. For instance, Australia's Melbourne Metro Tunnel project requires sustainability in design, including measures for climate change resilience. Victoria's standard PPP agreements outline specific natural hazards as force majeure events. In the United States, the State Government of Texas mandates consideration of extreme weather impacts in drainage design. Similarly, the OECD countries, such as the UK, exclude financial compensation for climate-related events from force majeure clauses, reflecting a shift towards recognizing foreseeable risks. Japan's PPP guidelines define force majeure, emphasize disaster resilience and risk sharing. While Sendai City refines force majeure definitions using historical disaster data to enhance project planning and emergency response. (See Annexure 1 for more details)

These international good practices can be referred to incorporate the most suitable resilience measures within the existing and upcoming infrastructure projects in India.




Standard documents reviewed	
	<p>Road Sector:</p> <p>Revised standard EPC Agreement for NH and Centrally sponsored road works proposed to be implemented on EPC Mode</p>
	<p>Railway Sector:</p> <p>Standard EPC Tender Document for Single Stage Two Packet System</p>
	<p>Power Sector:</p> <p>Revised Guidelines and Standard Bidding Documents SBDs for procurement ISTS through TBCB process</p>

Figure 9: Selected standard agreement documents for appraisal from the three sectors

Key findings derived from each sectoral contractual agreement and standard document:

In the road sector, the current EPC agreements lack provisions for safety and disaster resilience. The safety responsibilities are allocated to the authority, leaving contractors without any obligations in this regard. Moreover, there is a lack of regular safety evaluations by a safety consultant throughout the project lifecycle. In the railway sector, the scope of work does not incorporate disaster resilient features, leading to ambiguity regarding the nature and causes of damages that the contractor is obligated to



United States of America

Facility Concession Agreement between Texas Department of Transportation and the SH 130 Concession Company:

Construction must meet the Technical Requirements, including evaluating all drainage structures for a 100-year storm event, as specified in section 12.3 of the Facility Concession Agreement.²



United Kingdom

Treats weather events separately from 'force majeure':

A key issue is whether climate change impacts are covered by relief or force majeure clauses in PPP contracts, potentially making the government liable for unforeseen risks. In the UK, concessionaires are not compensated for hydro-meteorological events, despite increasing foreseeability based on scientific evidence.³



Australia

Melbourne Metro Tunnel - Tunnel and Station PPP Project Agreement:

The private partner must ensure sustainable and climate-resilient designs at all stages, with a Sustainable Design Report required at each stage.

The Partnerships Victoria standard Project Deed - considered as the market standard PPP position:

It provides a list of force majeure events like extreme winds exceeding specified speeds, as recorded by the Bureau of Meteorology, Melbourne, earthquake, floods expected once every 100 years etc.¹

Treats weather events separately from 'force majeure':

A key issue is whether climate change impacts are covered by relief, compensation, or force majeure clauses in PPP contracts.

These clauses can indemnify the concessionaire, potentially making the government liable for unforeseen risks.³



Japan

Resilient Infrastructure Public-Private Partnerships (PPPs):

Contracts and Procurement: Japan's PPP/PFI guidelines define force majeure as unavoidable natural or man-made disasters external to the parties' actions. Examples include storms, floods, earthquakes, and acts of terrorism or war.⁴

Sendai City - Iterative Processes to Enhance Understanding and Risk Sharing between the Public and Private Sector:

Sendai clarified force majeure provisions using seismic data and historical disasters, assessing natural hazard damage by comparing nearby buildings. This improved DRM clarity, private sector risk consideration, and emergency responses, with disaster risks increasingly shared based on project characteristics.

Concessionaire Screening Using DRM Evaluation Criteria in Airport PPP Projects - Evaluation of a Concessionaire for Kansai International Airport:

The screening of concessionaires gave positive evaluation to private operators that ensured stable, reliable airport operations with adequate DRM and reserve funding. It also positively evaluated those prioritizing safety through preventive and systematic maintenance and renovation investments.⁵

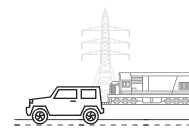


Colombia

Colombia's 4th Generation Road Concession PPP:

The 2010-2011 La Niña floods led to disputes over repair costs, prompting the national infrastructure agency to clarify insurance requirements. Concessionaires are now responsible for climate risks and must hold sufficient insurance.⁶

Figure 10: Snapshot of international good practices on mainstreaming disaster resilience aspects into standard contractual documents



1.4.4 Overall Resilience Gap Analysis

Building resilient infrastructure requires strengthening policy frameworks, integrating risk considerations into development and project processes, and enhancing the capacity of stakeholders. It also involves securing dedicated financing, applying cost-benefit tools and ensuring resilience across all project phases.

The literature review, stakeholder consultations, and analysis of sector-specific standard documents have highlighted key areas or domains that need focus. Critical gaps in the roads, railways and power sectors have been systematically categorised within these domains,

necessitating targeted interventions to enhance disaster resilience. The five key gap areas are as follows:

1. **Gaps in Standard Contractual Documents**
2. **Gaps across the Project lifecycle**
3. **Gaps in Data and Risk Assessment Systems**
4. **Gaps in Capacity**
5. **Gaps in Financing and Risk Coverage**

A summary of gaps identified across the five areas has been enclosed in Figure 11

1 Gaps in Standard Contractual Documents

- Codes & standards not updated
- Lack of disaster management Standard Operating Procedures
- Limited resilience consideration within sectoral policies
- No policy ensuring equitable risk and responsibility allocation
- Hazard events not defined in the force majeure clause
- Defect Liability Period in contractual agreements is very short
- No provisions for revisiting design codes and material specifications

2 Gaps across the Project lifecycle

- No provision to ensure resilience within project stages
- No reference to hazard impacts and resilience in authority and concessionaire obligations
- Does not mandate the Authority or Contractor to understand disaster risks and ensure disaster resilience
- No provision to mandate due-diligence and monitoring
- Lack of quality-based performance monitoring
- No provisions to ensure asset resilience during the operation and maintenance

3 Gaps in Data and Risk Assessment Systems

- Data gap in risk information
- Lack of clarity in project requirement specifications
- Lack of risk consideration and action plan for projects in disaster-prone areas
- Diversity of hazard risks and future threats is not considered
- Risk and responsibility are not clearly defined between private and public parties

4 Gaps in Capacity

- Lack of technical expertise in terms of disaster risk reduction
- DPRs lack disaster resilience experts for incorporating resilience specifications
- Absence of skilled experts mobilized on the ground to oversee resilience considerations
- Absence of resilience criteria during project evaluation

5 Gaps in Financing and Risk Coverage

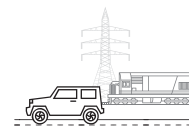
- Resilience financing is missing in maintenance contracts
- Lack of methodology to justify the resilience cost and investment
- Limited provisions for insurance and reinsurance for disaster risks
- Current insurance is secured by contractors only till the construction phase
- No equitable allocation of financial risks arising from natural hazards

Figure 11: Summary of gaps identified across the area



2

Recommendations for Mainstreaming Disaster Resilience



Recommendations for Mainstreaming Disaster Resilience

The chapter outlines 11 recommendations aimed at addressing the gaps identified across the five key areas outlined in Chapter 1. These gaps were identified following an extensive appraisal and review of standard contracts, a review of international best practices and extensive stakeholder consultation. The recommendations include

suggestions for modifications to standard agreements for more equitable risk sharing, mandatory risk assessments for priority projects, centralized data systems, a cost-benefit analysis tool for assessing the financial viability of resilience measures and more.

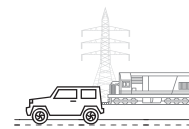
Table 3: Summary of Recommendations for Enhancing Infrastructure Resilience

Sections	Recommendations
Section 1: Revision of Standard Contracts	1. Embed resilience clauses in contracts and concession agreements
Section 2: Resilience interventions across the project lifecycle	2. Incorporate resilience in asset design beyond codal minimums 3. Ensure real-time monitoring and resilience compliance during implementation
Section 3: Establishment of data systems and risk assessment protocols	4. Create a centralized Disaster Risk and Infrastructure Data platform 5. Mandate standardized Hazard Risk and Vulnerability Assessment (R&VA) for priority projects 6. Define local Hazard Thresholds and Risk Benchmarks
Section 4: Capacity development	7. Institutionalize Resilience Expertise in Infrastructure Project Lifecycle
Section 5: Financing and market-based risk solutions	8. Create a dedicated India Infrastructure Resilience Fund (IIRF) 9. Standardize definitions for 'Resilient Infrastructure Investment' 10. Explore the idea of a Sovereign Risk Pool 11. Utilize innovative products for transferring disaster risk

The recommendations also align with findings from UK India infrastructure financing bridge report.

The UK India report highlights the importance of investor centric approach, with clarity needed for investors on three priorities while preparing projects:





Risk:

Identification & screening of projects for risks including climate & disaster risks is critical to reduce uncertainty. The mainstreaming disaster resilience study (the study) helps does that by suggesting a high level screening of priority projects (based on high level risk profile along with economic significance and network redundancy) and by suggesting a standardised HRVA (Hazard Risk & Vulnerability assessment) for such projects.

Return:

The study also provides a tool (RCBA) for quantifying the project level disaster risks in monetary terms and for assessing the costs & benefits of incorporating additional resilience measures to mitigate the risks through financial indicators such as IRR, NPV, BCR, Debt service coverage ratio etc.

Value:

The investors are also interested in looking at the value generated by projects, going beyond financial returns to include economic, social, & environmental impacts. Furthermore the alignment of projects with Sustainability & Resilience agenda will help attract investors who look for long term value & predictability rather than short term gains.

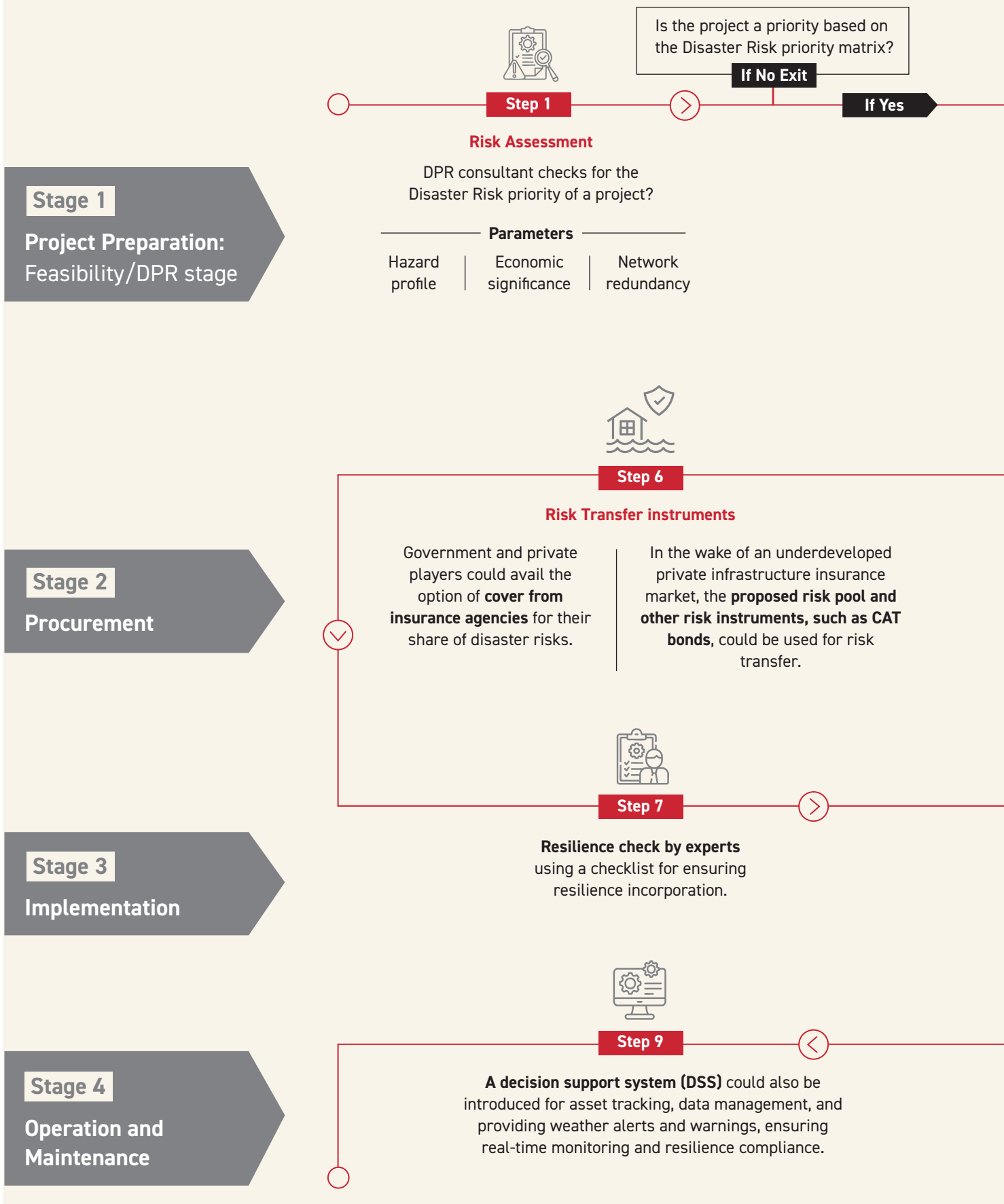
Highlighting the adaptation co-benefits can also make the case stronger.

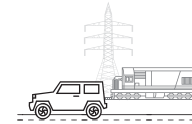
The study also emphasises on highlighting the value added component by suggesting a checklist for project appraisal that consists of all the above mentioned components (refer to Annexure 8).





Recommendations across the project lifecycle





Step 2

HRVA is mandatory

Using a Standardized template for HRVA (to be developed by the Line ministries)

Using data from the Centralized Disaster Risk and Infrastructure Data Platform to inform HRVA, besides site-specific investigations



Step 3

Risk-informed design

Mandatory HRVA:

Localized hazard thresholds are assessed for risk sharing at the procurement stage.

Voluntary:

Using the RCBA tool, the business case for additional resilience measures beyond codal minimums can be ascertained by the DPR consultant and suggested for incorporation.



Step 4

Enforcing resilience incorporation through

Checklist for Resilience expert to ensure risk assessment & risk-informed design at DPR stage

Checklist for EFC/SFC/PIB/DIB/PPPAC: For project appraisal



Step 5

Tendering and contracting stage

For both EPC and PPP projects

Equitable risk allocation is to happen based on project-specific hazard thresholds

Based on HRVA results, Project-specific Hazard Thresholds are to be incorporated into the RFPs and post-selection, into the final contracts awarded.

Force Majeure: where for hazards above the threshold, the risk is borne by the Government, and for hazards below the threshold, the risk is borne by the concessionaire.

DLP: Extension of the Defect liability period



Step 8

Resilience check by experts for ensuring resilience incorporation

2.1 Revision of Standard Contracts



Objective:

Institutionalize resilience through changes in standard contractual documents.

Recommendation 1: Embed resilience clauses in contracts and concession agreements

To mainstream resilience, standard bidding documents and contractual agreements across identified key infrastructure sectors need modifications. These modifications shall ensure incorporation of resilience measures and stakeholder accountability throughout the planning, design, construction, operation and maintenance phases.

Some key modifications within the contractual clauses and standard documents to effectively integrate resilience considerations are:

■ Define force majeure

Currently, the force majeure clauses in agreements consider natural hazards as 'Acts of God', whereas the assets are designed to withstand specific intensities of natural hazards. There should be a provision for including natural hazards under Force Majeure with clearly defined hazard types and thresholds for parameters such as intensity, frequency, duration and spatial extent to determine damage liabilities.

This can also be used to define and estimate the contingent liabilities of the authority and the party responsible for the design. Each project's threshold must be specific based on asset type and site location. For example, Japan's toll road concession project, defines the intensity of natural events above which the authority will bear additional costs.

■ Allocate equitable responsibilities

It is essential to promote equitable allocation of risk and responsibility to relevant stakeholders to ascertain liabilities in cases of hazard impacts. This distribution should be specified about the hazard thresholds established by the Project Implementing Authorities based on HRVA results from the DPR stage authority, taking into account parameters such as intensity, frequency, duration and spatial extent.

An iterative approach should also be adopted to allocate risk to the private sector, depending on the maturity of the insurance and PPP markets. Insurable risks should also be identified and transferred to the private sector.

■ Extend defect liability period

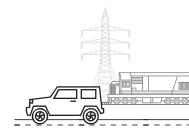
Presently, the defect liability period under the EPC construction mode is very short, ranging up to five years after the assets are commissioned, depending on the infrastructure sector. Also the model contract often defines defect liability only for specific components like pavements. However, extending it to the entire asset and for longer durations would better address construction deficiencies and quality issues.

This extension would place greater responsibility on the contractor to keep the asset operational for a more extended period (maybe with additional cost implications). Accordingly, the contractor may modify the cost estimates to incorporate the cost of liabilities for a longer period. This adjustment would resolve major issues related to material quality and artistry in construction, with improved monitoring and evaluation by the contractor to ensure asset durability and resilience.

Ministry of Road Transport & Highways, Government of India (MoRTH) has recently extended the DLP for Engineering, Procurement and Construction (EPC) projects upto 10 years, other ministries are also urged to consider it.

The toolkit developed under the study contains a list of resilience measures that suggest modifications to relevant clauses within the standard bidding documents and contractual agreements of the three selected infrastructure sectors. More details on the toolkit have been enclosed in Chapter 4.





Context

- There is a need for integrating disaster resilience measures to enhance project sustainability, where it is equally important to incorporate specific 'disaster resilience' clauses in standard contracts.
- The appraisal of the selected standard bidding documents/model concession agreements reveals several gaps in incorporating disaster resilience considerations while implementing projects. The gaps identified are as follows:
 - Historical/future data of natural calamities and their impact on similar assets are not assessed.
 - There is insufficient integration of disaster resilience measures in accordance with the local hazard profile for specific project locations.
- The timelines accorded to DPR agencies for DPR preparation are often inadequate for carrying out detailed investigations for a more risk-informed design.
- There is no guidance specifically on necessary disaster resilience codes to be followed for specific types of infrastructure in specific locations.
- The non-inclusion of disaster resilience measures by the contractor/concessionaire should qualify as an 'Event of Default'.
- The definition of force majeure does not clearly define natural hazards and their risks.
- The insurance coverage is inadequate. This gap will be discussed in detail in the upcoming section.

International Good Practice Example: Resilience Clauses in Contracts and Concession Agreements

Japan's Toll Road concession project: In Japan's Aichi Toll Road Concession Project, the government bears costs

only for unforeseeable force majeure events i.e if the concessionaire couldn't have foreseen & thus prepare for them. Risk allocation for public and private parties is done based on hazard parameters.

Disaster type	Events for which the public sector bears additional
Earthquake	Damage based on normal social conventions
Heavy rain	Maximum rainfall of 80mm or more in 24 hours. Even if rainfall is below the above standard, it is considered heavy rain if hourly rainfall is significant (20 mm or more), provided that the hourly rainfall is observed at the nearest weather observation station (managed by the public corporation) from the damaged place.
Storm	Maximum wind speed of 15 m per second or more (average in 10 min)
High tide, storm surge, and tsunami	An extraordinarily high tide, storm surge, or tsunami caused by a storm or its aftermath, with relatively minor damage.

Action Plan

Action	Responsibility
Develop a model framework for determining hazard thresholds for specific assets and hazard types to be integrated into the Force Majeure framework.	NDMA/SDMA, in collaboration with implementing agencies
Ease funding allocations and modifications in the model documents.	Line Ministries—modify documents/policies and prepare evaluation criteria for funding. Niti Aayog and other relevant ministries—approve.

2.2 Resilience interventions across the project lifecycle



Objective:

Operationalize resilience across the project lifecycle: planning, design, construction and maintenance of assets.

Planning, Design and Construction stage

Recommendation 2: Incorporate resilience in asset design beyond codal minimums

■ Beyond codal minimums:

To develop more resilient infrastructure, infrastructure projects need to exceed the minimum design standards set by respective standard-setting bodies, enabling them to adapt and provide better mitigative resilience against local hazard risks (e.g., flooding, landslides and earthquakes). This may include incorporating stronger infrastructure as part of the design, protective measures, provision of redundancies and increased preparedness based on the specific data and experiences of local hazards.

■ Localized resilience measures:

To include new construction technologies and innovative mechanisms for project implementation. The use of local technology with stakeholder and community involvement may help achieve more resilience at the project and community levels (based on community experience). Integrating these local and indigenous measures in design can help increase resilience in a financially viable way.

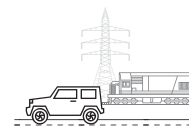
■ The cost-benefit of additional resilience provisions:

Incorporating additional resilience provisions into the project design will entail certain costs. To ensure the viability of the investment, it is crucial to compare the quantifiable benefits of incorporating additional resilience measures during project design and implementation. This necessitates a precise cost-benefit analysis at the asset level. **The RCBA tool has been developed, enabling users to evaluate the benefits of investing in resilience and building a strong economic case. More details on the RCBA tool can be found in Chapter 3.**

■ Context

- In recent years, significant efforts have been made to develop standards and guidelines to mitigate disaster risks. These initiatives have gained importance due to the increasing frequency and intensity of natural hazards observed over the last few decades. Specifications in design guidelines are checked periodically by standard-setting bodies to adapt to changing hazard scenarios, with revisions to design codes occurring every 5 to 7 years. However, in some regions, these updates might be necessary every three years.
- Technical bodies within the Government of India, such as the Indian Road Congress (IRC), Research Designs and Standards Organisation (RDSO), Central Electricity Authority (CEA), and the Bureau of Indian Standards (BIS), have played a crucial role in developing guidelines, codes, and standards that enhance disaster resilient infrastructure designs. A comprehensive list of these guidelines, design codes, and standards for building resilient infrastructure has been enclosed in Annexure 5.
 - IRC provides guidelines for earthquake-resistant road structures, standards for flood-resistant embankments and drainage systems, and measures for landslide prevention in hilly areas.
- The RDSO focuses on developing and updating standards to ensure railway infrastructure is resilient against natural hazards (e.g., earthquake, flood, landslide) while also integrating the latest technologies through research and stakeholder collaboration.
- The CEA develops and updates standards to ensure that power sector assets withstand hazards (e.g., cyclones) while also monitoring compliance and incorporating technological advancements.
- The BIS sets disaster resilient infrastructure standards, ensuring structures are safe and durable enough to withstand natural hazards. While these codes provide the minimum design standard and specification, the asset design should not only adhere to such updated design codes and standards but also consider keeping additional provisions beyond the codal provisions.

Figure 12: Snapshot of RCBA tool dashboard



Action Plan

Action	Responsibility
Study structural measures in international to local good practices.	Implementing agencies – Approve and incentivize additional resilience measures.
Stakeholder involvement.	Technical Bodies – Design review.
Upgradation and suggested inclusions in the codes.	
Create an environment that enhances financial incentives for private players investing in resilience.	DEA – Enhance financial incentives for public and private investment in resilience.

Operation & Maintenance Stage

Recommendation 3: Ensure real-time monitoring and compliance with resilience during implementation

Utilize digital monitoring tools (e.g., DSS) to track asset performance and receive hazard alerts. A decision support system (DSS) can also be introduced for asset tracking, data management, and providing weather alerts and warnings.

A DSS blueprint has been created as an example for infrastructure monitoring, considering the flood hazard.

The key parameters for building an IT-based decision support system are as follows:

■ Water level in rivers and streams:

Real-time data on water levels in rivers and streams can help identify potential flooding areas, allowing for proactive steps to secure the distribution network and assets in those areas.

■ Rainfall data:

Real-time rainfall data can help predict the likelihood and potential severity of floods in different areas.

■ Asset tracking and management data:

Data on the location and condition of infrastructure assets can help identify assets at risk of damage from floods, facilitating proactive steps to secure them.

■ Flood maps:

Maps that show the areas at risk of flooding can help identify potential hotspots and proactively take steps to secure the infrastructure assets in those areas.

■ Weather alerts and warnings:

Real-time alerts and warnings about severe weather conditions can help implementing agencies take proactive steps to secure their infrastructure assets before floods occur.

■ Predictive analytics:

Predictive analytics can help forecast the potential severity of floods and identify areas that are at risk of being flooded.

■ Communication and collaboration tools:

Tools that enable communication and collaboration between different stakeholders, including government agencies, first responders and the private sector, can help ensure a coordinated response to floods and minimize the loss of assets.

Example of individual platforms that can be used to provide data to power a DSS for each of the following data/parameters are shown in Figure 13.

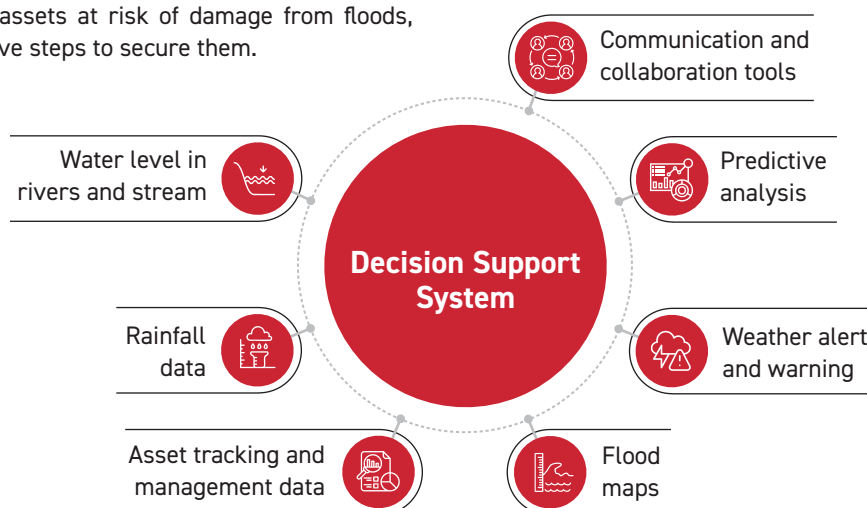


Figure 13: Key parameters for building a decision support system

Water levels in rivers and streams

- Central Water Commission's Water Resources Information System (WRIS)
- India Water Portal
- National Hydrology Project (NHP)
- National Water Informatics Centre (NWIC)
- Flood Forecasting and Warning System (FFWS)



Rainfall data

- India Meteorological Department (IMD)
- National Remote Sensing Centre (NRSC)
- Ministry of Earth Sciences (MoES)
- Climate Data Online (CDO) from National Oceanic and Atmospheric Administration (NOAA)
- NASA Global Precipitation Measurement (GPM)



Asset tracking and management data

- Enterprise Asset Management (EAM) software
- Global Positioning System (GPS)
- Geographic Information System (GIS)



Flood maps

- National Remote Sensing Centre (NRSC)
- National Disaster Management Authority (NDMA)
- Indian Space Research Organisation (ISRO)
- OpenStreetMap
- Google Maps



Weather alerts and warnings

- India Meteorological Department (IMD)
- National Oceanic and Atmospheric Administration (NOAA)
- European Centre for Medium-Range Weather Forecasts (ECMWF)
- World Meteorological Organization (WMO)



Predictive analytics

- Apache Hadoop
- Apache Spark
- R
- Python
- MATLAB

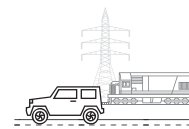


Communication and collaboration tools

- WhatsApp
- Email
- Radio Bulletin
- Mobile Communication
- Walkie Talkie
- Satellite Phone
- QRT



Figure 14: Illustrative platforms to provide data for developing a DSS



▪ **Context**

▪ In India, project monitoring is carried out in the construction phase only, while the O&M phase lacks active monitoring and regular quality checks. Further, real-time monitoring at the operational phase is only present in select sectors, such as transmission.

▪ **Good Practices:**

▪ **The Infrastructure & Project Monitoring Division (IPMD)** performs a triple role in monitoring the implementation status of central sector projects costing more than \$17.49 million in 16 infrastructure sectors. It also oversees the performance of 11 key infrastructure sectors (Gol, 2024).

▪ **The proposed PMGSY-** Online management and monitoring system will have an efficient user interface featuring key components, including planning and analysis, designs, approvals and tendering, execution and monitoring, fund disbursement and payments, and transfer of assets.

▪ Further, innovative technologies should be explored to monitor projects across all the project phases. **A list of a few good practices for project monitoring has been enclosed in Annexure 6.**

Action Plan

Action	Responsibility
Prepare an inventory of existing early warning systems and prepare a dissemination strategy for infrastructure asset managers.	CDRI—Initiate the study NDMA—Facilitate with district-level EWS ecosystems
Develop communication systems for sharing early warning system data with countries impacted by natural hazard events in India.	CDRI—Anchor the initiative NDMA/SDMA—Data governance and dissemination

2.3 Establishment of Data Systems and Risk Assessment Protocols



Objective:

Develop standardized and interoperable data systems to inform risk-based infrastructure planning.

Recommendation 4: Create a centralized Disaster Risk and Infrastructure Data Platform

■ **Data platform:**

A standard data platform or directory needs to be developed to enable one-stop access to disaster risk data. The platform should host data **on hazard occurrences and their impacts, including information on infrastructure**

asset exposure, damages and associated losses, in a standardized manner. It should be established and maintained by a designated government agency **such as the NDMA.** Furthermore, this database must be regularly updated to ensure the accuracy, reliability and relevance of its data for evidence-based decision-making and risk-informed planning.

■ **Sensitization and training:**

Additionally, line ministries, implementing agencies and private stakeholders should be sensitized through training and workshops on recording and sharing relevant data on the platform, as well as on the utilization of disaster risk information from the platform for informed decision-making.

▪ **Context**

- India's National Policy on Disaster Management (2009) encourages the utilization of geographic information systems (GIS)-based databases, notably the National Database for Emergency Management (NDEM), which compiles and disseminates data on natural hazards.
- Complementing this, the National Spatial Data Infrastructure (NSDI) aggregates spatial data from various agencies. The policy underscores the need for sharing thematic and spatial data for effective policy analysis and includes a ground check component for hazard zonation mapping and vulnerability analysis based on GIS and remote sensing data.
- Further reinforcing data accessibility, the National Geospatial Policy (2022) (GoI, 2022) seeks to improve data availability and access of data across organizations and sectors as part of its 2025 goals. However, challenges persist due to the lack of data standardization and mechanisms for sharing databases between different ministries. This has

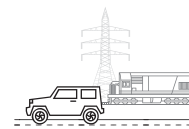
made it difficult for stakeholders to access data and keep up-to-date data records of critical infrastructure.

International Good Practice Example: Data Systems

- Some countries, like the UK, Australia, and Japan, have included mechanisms for hazard and infrastructure data collection, maintenance, and dissemination within their policies and regulations, whereas some have only suggested their incorporation.
- The Open Data Policy (M-13-13) issued by the Office of Management and Budget (OMB) in 2013 in the USA focuses on making information resources discoverable, accessible, and usable for everyone. It formulates a framework for institutionalizing principles of effective information management at each stage of the information life cycle. Under the policy, different sectors are required to make a model plan to manage data, which includes the infrastructure sector (U.S. Gov, 2013).

Action Plan

Action	Responsibility
<p>Create a standardized data structure to</p> <ul style="list-style-type: none"> • Investigate data availability, consultations with line ministries • Propose a governance system • Create an access portal and dashboards 	<p>NDMA—Data Governance</p> <p>Implementing Agencies—Data Provider</p> <p>Line Ministries—Facilitator</p>
<p>Develop communication systems for sharing early warning system data with countries and local authorities impacted by natural hazard events in India.</p>	<p>CDRI—Anchor the initiative</p> <p>NDMA/SDMA—Data governance and dissemination</p>
<p>Prepare and identify probabilistic hazard data for asset-level risk assessments.</p>	<p>CDRI—Explore the best fit historic and future hazard data sources</p>
<p>Enhance the resolution of risk indices, such as GIRI, to accurately assess local-level asset exposure and vulnerability.</p>	<p>Line Ministries—Confirm existing data used and the applicability of probabilistic data</p>



Recommendation 5: Mandate standardized hazard risk and vulnerability assessment (HR&VA) for priority projects

■ The concerned ministries need to mandate **Hazard Risk and Vulnerability Assessments of priority infrastructure projects, based on detailed site-level investigations, to identify and address disaster risks at the planning and design stage, and to incorporate resilience measures.**

■ The identification of projects for mandatory **HR&VA should be based on a Disaster Risk Matrix** that evaluates projects on **three key parameters**: Projects that lie in a vulnerable region as per the hazard profile criteria, or projects that are economically significant and have low network redundancy.

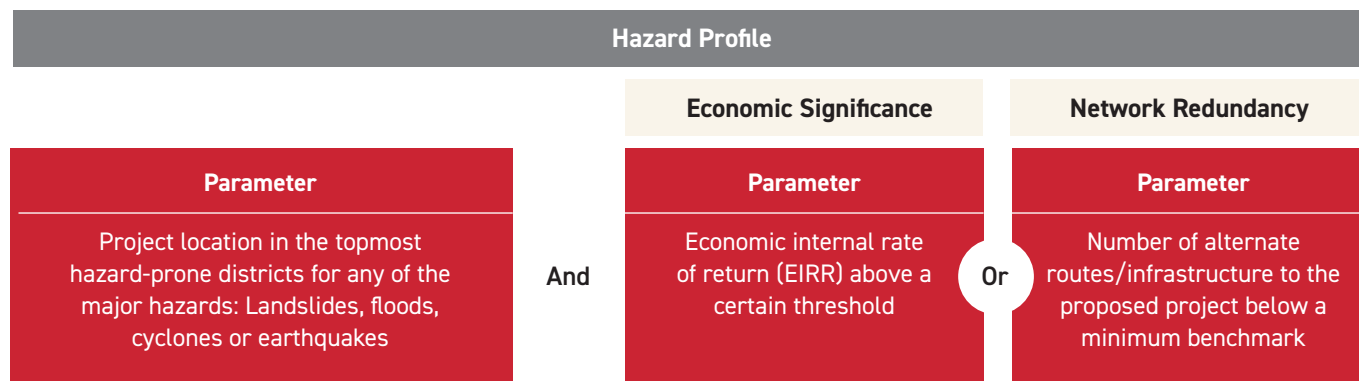


Figure 15: Disaster Risk Priority matrix for selection of projects

■ **Disaster Risk Assessment component should be incorporated into the Project appraisal process.**

■ **The format for the PIB/DIB memorandum for appraisal of projects** should include the following questions to ensure that projects prepared are Resilient and in line with an investor centric approach (See Figure 15):

- Whether the project falls in the priority category based on the Disaster Risk Priority Matrix?
- Whether the Detailed Project Report consists of findings from **'Hazard Risk & Vulnerability Assessment' under the risk analysis?**

Refer to Annexure 8 for a detailed checklist

■ **RCBA tool (See Recommendation 4)** could be used to inform the cost-benefit analysis section in the DPRs and to make a case for additional resilience measures.

■ **A standardized risk and vulnerability assessment template should be developed to ensure uniformity in the assessment approach across infrastructure projects.** Historical data could inform this assessment of the impacts of natural hazards across various asset classes, made available through the proposed disaster data platform (see Recommendation 4), as well as information from detailed site-specific investigations.

Context

- Currently, there is no mechanism for making risk and vulnerability assessment mandatory during project initiation.
- For the National Action Plan on Climate Change (2008), the Department of Science and Technology (DST) conducted vulnerability assessments for key sectors, including power infrastructure.
- Various infrastructure projects, such as the Mumbai Coastal Road Project, Talcher Thermal Power Project, and Chennai Metro Rail Investment Project, have conducted risk and vulnerability assessments to gauge the infrastructure asset risks.
- DPRs for road projects, such as those under the Pradhan Mantri Gram Sadak Yojana (PMGSY), typically include sections addressing environmental concerns and hydrological surveys that target specific hazard risks like flooding (GoI, 2024). Similarly, DPRs for railway projects incorporate various surveys and safety assessments
- However, the application of hazard risk assessment is inconsistent across different sector projects (Kumar, 2024). One of the key reasons is the lack of adequate

hazard data to carry out such assessments. Further, significant gaps in enforcement and standardization hinder the integration of comprehensive risk assessments into project planning.

- Incorporating standardized procedures for risk and vulnerability assessment is important to ensure a better understanding of disaster risk and infrastructure vulnerabilities, which will help build resilience in existing and new assets.

International Good Practice Example: Standardized Hazard risk and vulnerability assessments

Countries like Japan, the UK, and the USA have established procedures for risk and vulnerability assessments in their policies and action plans. In Japan, to refine and update adaptation and resilience measures, the Fundamental Plan for National Resilience (2018) includes procedures for vulnerability assessments, which are currently in practice. It includes anticipating risks posed by large-scale disasters, analyzing the possible processes in which disruptive events can occur, assessing the disaster vulnerability of each sector and conducting cross-sectoral analysis of disaster mitigation measures (GoJ, 2018).

Action Plan

Action	Responsibility
Prepare Standard Operating Procedures (SOPs) for detailed site investigations during the project planning and design stages.	CDRI – Suggest SOP modifications Technical Bodies – Validate and incorporate into codes and standards
Include detailed risk and vulnerability assessments in the standard DPR proforma and sectoral codes and standards.	Line Ministries and Implementing Agencies – Ensure enforcement

Recommendation 6: Define local Hazard Thresholds and Risk Benchmarks

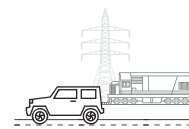
- Project Implementing Authorities in the infrastructure sector should establish thresholds for hazard parameters

that are contextual to the site and project. By setting these thresholds, they can determine the levels of risk and allocate responsibilities among the involved parties, accordingly, thus enhancing the overall resilience of infrastructure projects.

Context

In India, infrastructure authorities do not set hazard thresholds based on the specific risks and vulnerabilities of the site and project, often due to limitations in technical expertise and resources (Saini, 2024). However, adopting this approach can lead to a more precise assessment and

management of the unique risks faced by each asset located in a specific geography, ensuring disaster risk mitigation and building resilience in infrastructure projects



Action Plan

Action	Responsibility
Prepare and identify probabilistic hazard data for asset-level risk assessments.	CDRI – Explore the best fit historic and future hazard data sources.
Increase the resolution of risk indices like GIRI to assess local-level asset exposure and vulnerability.	Line Ministries – Confirm existing data used and the applicability of probabilistic data.
Develop a model framework to determine hazard thresholds for specific assets and types of hazards.	NDMA/SDMA in collaboration with the Implementing Agencies/local authorities
Prepare a model project-level risk management framework with live project and stakeholder involvement based on hazard thresholds.	CDRI – Conduct a study on the disaster risk management framework.

2.4 Capacity Development



Objective:

Build national and local capacity to implement, monitor and scale resilience measures.

Recommendation 7: Institutionalize resilience expertise in infrastructure project lifecycle

- The involvement of a resilience expert in an infrastructure project is crucial for maintaining compliance with disaster resilience measures across design, construction and Operation & Maintenance (O&M) stages. The resilience expert can also suggest resilience considerations in the O&M manual, as well as oversee monitoring and audits during the O&M phase. This expert should operate independently of the contractor/concessionaire, allowing for unbiased supervision and thorough independent proof checking.

- To facilitate this process, a comprehensive list of empanelled resilience experts should be created under the appropriate line ministries. Implementing authorities can then involve experts from this list for their supervision and monitoring needs. .

Resilience Expert:

Refers to sector-specific technical experts who have a comprehensive understanding of various hazards and their impacts on assets.

- A detailed checklist that outlines resilience considerations specific to various types of infrastructure assets will further empower these experts to effectively evaluate and monitor infrastructure at various stages of its lifecycle. The resilience toolkit developed under this study includes such a list, which line ministries can enhance with further details for use by the experts.

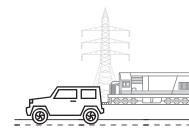
Sector-agnostic & sector-specific checklists have been provided for Resilience Experts in the Guidance document.

Table 4: Suggestive Sector agnostic checklist for the line ministries

Project phase	Checklist	✓/✗	Reference guidance document/ clause
Conceptualization and planning	1. Have you assessed the project site's comprehensive hazard, risk and vulnerability? A comprehensive hazard, risk, and vulnerability assessment for the project site involves systematically identifying potential hazards, analyzing the site's vulnerability to these risks and evaluating the risks. This process should include data collection, stakeholder consultation, and the development of mitigation strategies to minimize potential impacts.		
	2. Have you ensured the proposed alignment is stable and not prone to natural hazards or other adverse climatic conditions?		
	3. Have you considered climate hazards during the micro-site assessment?		
	4. Have you assessed the climate risks to which the site is/may be susceptible? Mention the method used to assess climate risks including but not limited to the following: <ul style="list-style-type: none"> ■ Historical data: Analyze historical weather and climate data to identify patterns of extreme weather events, such as floods, droughts, and storms; refer to local and regional climate reports. ■ Stakeholder engagement and participatory approaches: Conduct focus group discussions with local communities, experts, and stakeholders to gather insights and validate findings; use surveys and interviews to collect qualitative data on local knowledge, perceptions, and experiences related to climate risks. ■ Scenario analysis: This includes developing and analyzing multiple future scenarios based on different climate projections and socio-economic pathways. ■ Climate modelling and projections: Utilizing global and regional climate models to project future climate conditions and assess potential. 		
	5. Have you considered the climate parameters used to plan the asset during demand forecasting? Consider how climate parameters will influence demand loads on the asset under consideration such as: <ul style="list-style-type: none"> ■ Roads: Temperature variability, precipitation patterns, and heat waves ■ Railways: Temperature fluctuation, rainfall and flooding ■ Power: Temperature extremes, sea-level rise and coastal erosion 		

Action Plan

Action	Responsibility
<p>Modify standard documents according to the suggested changes outlined in the Disaster Resilience Toolkit.</p> <p>Prepare detailed wordings of the revised clauses in standard documents based on suggested modifications.</p> <p>Incorporate the changes in the documents.</p> <p>Disseminate revisions in the document.</p>	<p>CDRI – Suggest modifications</p> <p>Line Ministries – Modify documents with revised wordings in the clauses. Include the resilience checklist in standard papers and as part of the concept note for the approval committee</p>
<p>Prepare detailed job descriptions (JDs) and Statements of Work (SoWs) for disaster resilience experts to support project design, supervision and monitoring stages.</p> <p>Empanel a list of independent experts to be involved at various stages of the project to ensure disaster-resilience measures are implemented.</p>	<p>Line Ministries: Empanel experts</p>



2.5 Financing & Market-Based Risk Solutions



Objective:

Mobilize financial instruments, de-risk investments and create incentives for resilience.

Recommendation 8: Create a dedicated India Infrastructure Resilience Fund (IIRF)

Housing institution:

The fund can be housed under a financial institution (such as NIIF or NABFID).

Technical support:

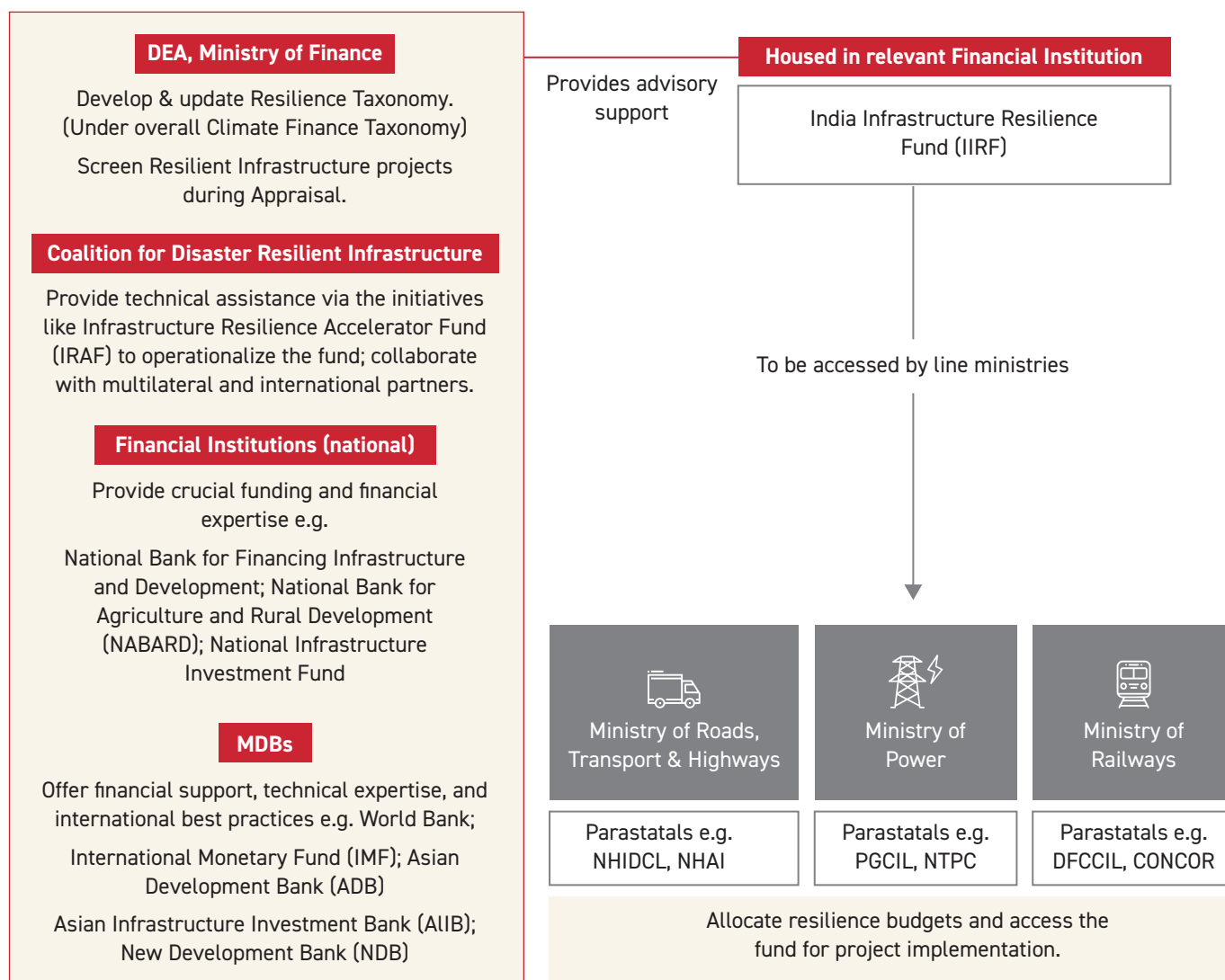
NITI Aayog, CDRI and multilateral organizations (such as WB, ADB, AIIB, etc.) could be crucial stakeholders providing advisory and technical support.

Funding sources:

The fund could be constituted using Government of India (GOI) contributions, Concessional/Adaptation finance from multilateral development banks (such as the World Bank, Asian Development Bank and Asian Infrastructure Investment Bank) and other international sources.

Funding criteria:

A strict project selection and eligibility criteria should be established. The projects of respective infrastructure line ministries, such as Roads (Ministry of Road Transport and Highways), Power (Ministry of Power) and Railways (Ministry of Railways), along with their respective parastatal organizations that meet the eligibility criteria, should be able to access the IIRF.



Purpose: Finance projects that enhance infrastructure durability and adaptability against adverse events.

Figure 16: An illustrative structure of the proposed India Infrastructure Resilience Fund (IIRF)

Action Plan

Action	Responsibility
<p>Creation of India IIRF</p> <ul style="list-style-type: none"> • Design the fund • Develop a detailed model of the fund • Identify and engage stakeholders, including financiers • Define screening criteria • Mainstream RCBA tool <p>Implement blockchain technology for targeted investments.</p>	<p>DEA—Facilitate the fund</p> <p>Financial Institution/intermediaries—House the fund</p> <p>CDRI—Technical advisory</p> <p>MDBs and IDAs—technical and financial support</p> <p>Line Ministry—project pipeline</p>
<p>Study of global taxonomies on resilience and resilience Taxonomy of India (under preparation).</p> <p>Prepare definitions of resilience interventions and projects for accessing resilience funds.</p>	<p>CDRI & NDMA</p>

Recommendation 9: Standardize definitions for 'Resilient Infrastructure Investment'

- To enhance market transparency and confidence, government authorities need to standardize the definition of 'infrastructure resilience investments' under India's Climate Finance Taxonomy.

- This will assist the private sector, government, multilateral development banks (MDBs) and development finance institutions (DFIs) by providing clear guidelines for identifying and evaluating resilient infrastructure projects.

Context

Resilience Financing Landscape in India

India's infrastructure financing is primarily public, with funds allocated through the Ministry of Finance and supplemented by investors like the **National Investment and Infrastructure Fund (NIIF)** and **India Infrastructure Finance Company Limited (IIFCL)**.

Despite initiatives like the **National Infrastructure Pipeline (NIP)**, challenges persist due to an existing infrastructure gap (WBG, 2024). The estimated resilience cost across sectors like power, transport, water, etc. is an additional **3 percent (As per WBG, 2019)**, which for NIP's size of \$1.4 trillion comes out to \$42 billion.

To mitigate long-term costs, **line ministries need to allocate additional funds to finance resilience initiatives**, besides MDBs and the private sector.

Role of MDBs and Private Sector

Multilateral development banks (MDBs) and development finance institutions (DFIs), including the **Asian Development Bank (ADB)**, **World Bank Group (WBG)** and **KfW**, support resilience financing through **grants, concessional loans, green bonds and blended finance**. However, stakeholder consultations reveal that **funding agencies lack specific resilience criteria** in project evaluations.

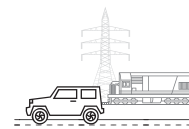
Private sector players like **Tata Group, Reliance Industries and Adani Group** lead climate-resilient infrastructure investments, particularly in **renewable energy projects**. Public-private partnerships (**PPPs**) further bolster urban resilience through models such as the **Hybrid Annuity Model (HAM)** for highways and initiatives like the **Smart Cities Mission (2015–2025)**.

Challenges

Despite efforts, private sector participation faces obstacles:

- **Inadequate localized climate risk data** makes it difficult for investors to assess risks and returns
- **Uncertain financial viability**, as resilience projects are perceived to have low or unpredictable returns (**WBG, 2021**)
- **Regulatory barriers**, including unclear policies and a lack of incentives (**Singh, 2021**)
- **Limited awareness and expertise** in resilience investment opportunities (**WBG, 2021**)

To address these issues, a fund could be established that would help reduce long-term maintenance and repair costs, easing out financial burden on governments. Also, by showcasing a commitment to resilience, it would attract domestic and international investors, boosting investor confidence.



Action Plan

Action	Responsibility
Prepare screening and evaluation criteria based on standard definitions and taxonomies.	DEA—Provide a mandate to prepare screening and evaluation criteria MDBs/DFIs—Establish resilience criteria

Recommendation 10: Explore the idea of a sovereign risk pool

■ An India

Risk Insurance Facility (IRIF) will help reduce the financial burden on governments of absorbing disaster risks (see Figure 17).

■ Housing institution:

IRIF could be housed within a Government Re-insurer such as GIC-RE, with the Ministry of Home Affairs/NDMA being a key stakeholder.

■ Participants:

The country's states, along with crucial infrastructure stakeholders at the central level, could be key participants in the facility.

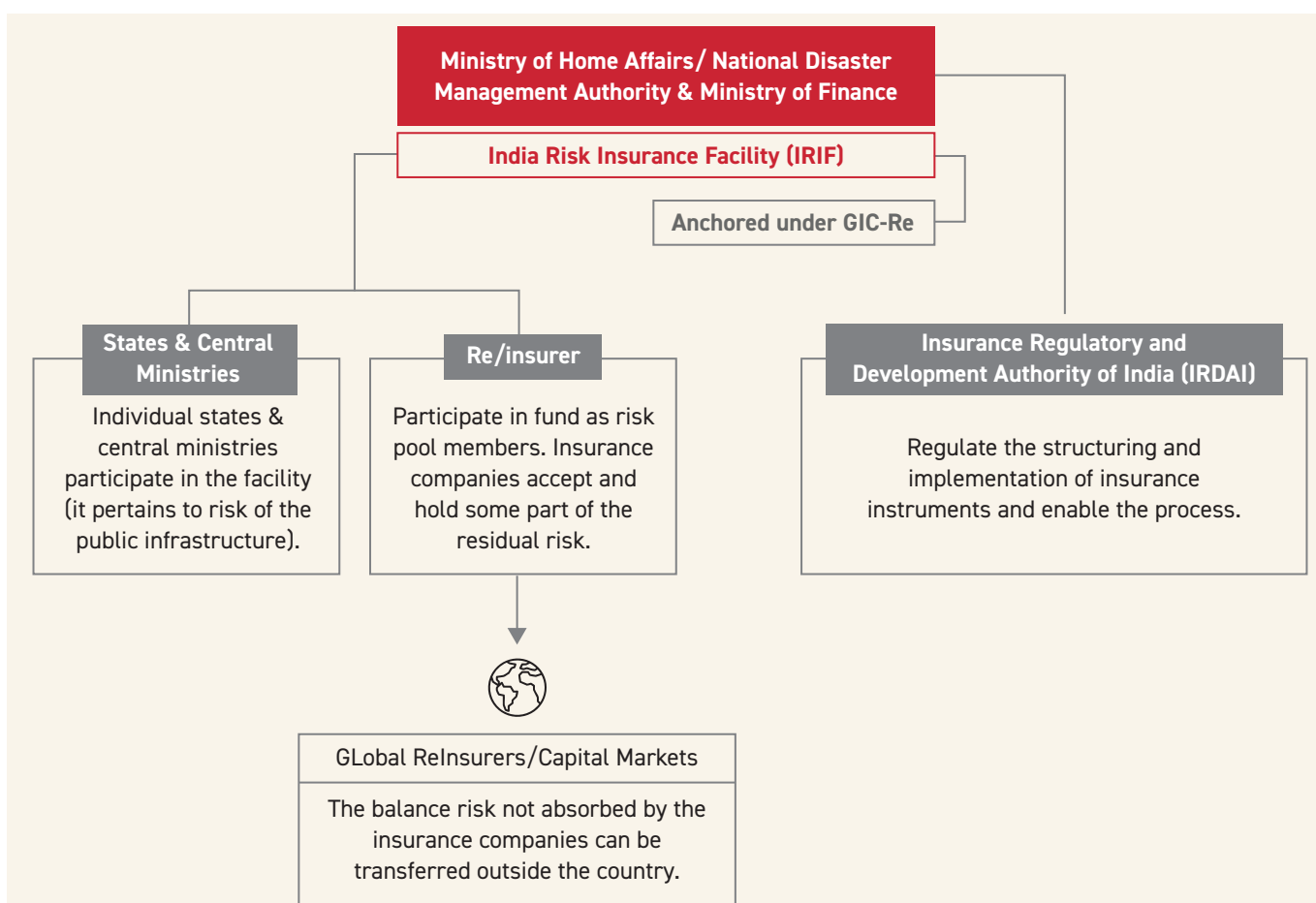
■ Reinsurers and insurers

Would also join as members, with insurance companies retaining some risk and transferring the balance to the internal market.

Technical and advisory support can be provided by MDBs, such as the World Bank and ADB.

Such a facility in India will be able to absorb larger risks and use ILS and international markets to increase its capacity.

For example, countries in the Caribbean, the Pacific, Africa and Southeast Asia are managing these risks through similar risk facilities with the support of the World Bank.



Purpose: Absorb residual risk (risk from public infrastructure) from the India Infrastructure Resilience Fund by transferring it to insurance companies and balance risk to outside the country.

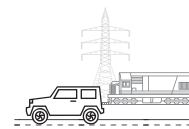
Figure 17: An illustrative structure of the proposed India Risk Insurance Facility (IRIF)

Action Plan

Action	Responsibility
<p>Creation of India IRF</p> <ul style="list-style-type: none"> • Explore risk-absorbing markets • Develop risk transfer mechanisms • Design the facility • Engage NDMA and IRDAI 	<p>NDMA—House the facility</p> <p>IRDAI—Regulatory support</p> <p>CDRI—Technical advisory and market assessment</p>
<p>Create risk pools at the national or international level among multiple countries with diversified risk portfolios that can provide financial relief in the event of disasters.</p>	<p>CDRI: Collaborate with NDMA for a detailed risk pool study</p>

• Context

- Insurance coverage across the infrastructure sector
- Insurance Gaps: Disasters cause significant losses to the infrastructure sector. The average annual economic losses from natural catastrophes have surged to \$8 billion (2013–22), a 125 percent increase from \$3.8 billion in the previous decade (2003–12). However, insurance protection against natural catastrophe risks in India is low, with 93 percent of exposures uninsured. Though there has been an improvement in natural catastrophe protection from 5.6 percent in 2016 to 6.5 percent in 2022, there remains a considerable gap.
- Existing scenario:
 - In existing practice, insurance policies procured by contractors and other consultants are limited to the duration of the contract. Further, the coverage primarily includes the following:
 - Third-party liability for individuals affected by the construction activities
 - Life insurance for workers engaged in the construction process
 - (The larger list of Infrastructure insurance policies in use in India is mentioned in Figure 19.)
 - The payment of premiums, required by government regulations, is incorporated into the overall contract pricing and value to safeguard the government from potential liabilities.
 - Throughout the contract period, infrastructure insurance predominantly **focuses on the construction phase**. The **'O&M' phase often faces coverage gaps** (Swiss RE, 2023). Also, the government is responsible for absorbing the financial risk for any losses to public infrastructure caused by natural hazards. Government fund is utilized for the repair and reconstruction of the asset to restore services. Furthermore, there are no mechanisms in place for swift insurance claims.
- Challenges:
 - Several challenges that impede efforts to bridge this catastrophic gap include a lack of awareness, low-risk perception, a lack of comprehensive risk assessments of public sector projects, fragmented insurance coverage, and underwriting (Swiss RE, India's insurance market: growing fast, with ample scope to build resilience, 2024) (see Figure 18).
- Demand side: In India's infrastructure sector, project insurance is often viewed as a 'commodity' rather than a 'risk transfer solution' (where the financial burden of potential losses is shifted from one party to other parties involved or to the market), as a result of financial constraints associated with lump-sum construction contracts. Contractors frequently opt for insurance policies with high deductibles to secure lower premium rates, which can result in insufficient compensation at the time of a claim (Swiss RE, 2023).
- Supply side: Individual insurance companies have limitations in the acceptance of risks. Even if these risks are accepted for due coverage, most of the insurers need robust risk transfer mechanisms. In some markets, the risk transfer mechanisms take place through:
 - Alternative risk Transfer Mechanisms like Insurance-Linked Securities and Catastrophe Bonds (CAT Bonds), etc.
 - 'Pools' or a 'consortium' approach
- These mechanisms are not in existence in the Indian market. Recently, a few companies have started accepting guaranteed risks like Performance Bonds to a limited extent. Beyond this, the insurers have no arrangements in the market to cover disaster risks for huge sovereign assets.
- Good Practices:
 - **A model that addresses resilience financing and risk coverage needs:** The **Climate Insurance-Linked Resilient Infrastructure Financing (CILRIF) Facility**, a long-term 'known price' insurance solution that incentivizes municipalities to invest in resilient infrastructure, can also be explored in the Indian context. The CILRIF facility, which includes both a 'Finance Facility' and an 'Insurance Facility', focuses on risk transfer and mitigation. It aims to incentivize resilience investments, provide access to affordable capital, reduce debt burdens, and promote sustainable development (TheLab, 2022).
 - **Risk Pools:** The Philippine City Disaster Insurance Pool (PCDIP) pools resources from participating cities to offer parametric insurance, ensuring rapid disbursements based on specific disaster metrics (ADB, 2018). , (WB, 2013). Such a type of risk-pooling mechanism can also be explored in the Indian context.



Lack of awareness and low perception of risk	Poor risk assessment for public sector infrastructure projects	Fragmented insurance coverage and underwriting
<p>Low awareness of natural catastrophe risks among Indian property owners, with only 16% recognizing risks like quakes and fires.</p>	<p>Pre-feasibility studies for public sector infrastructure projects often lack comprehensive risk assessments, and bidder selection criteria neglect risk management capabilities.</p>	<p>Infrastructure insurance is fragmented, with high deductibles causing inadequate claims coverage. Insurers struggle with underwriting due to rare natural catastrophes and inadequate risk models in India, leading to poor integration and frequent updates.</p>

Figure 18: Challenges impeding efforts to bridge the catastrophic gap

Source: Swiss Re Report (2024)

Fire insurance – Standard Fire and Special Perils Policy (SFSP)	Machinery Breakdown Insurance	Consequential Loss Policy	Contractor's All Risks (CAR) Policy
Erection All Risks (EAR) Policy	Advance Loss of Profits Policy	Electronic Equipment Insurance Policy	Boiler and Pressure Plants Policy
Contractor's Plant and Machinery Policy	Storage-cum-Erection Policy	Industrial All Risks Policy	Marine or Transit Policy

Figure 19: Infrastructure insurance policies: India

Source: Project Implementation Manual, Government of India (2010)

Recommendation 11: Utilize Innovative Products for Transferring Disaster Risk.

Innovative products, such as Catastrophe bonds (also known as Cat Bonds), resilience bonds, weather derivatives, parametric insurance and captives, are key products that can be explored to transfer disaster risks.

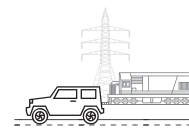
CAT Bonds hold immense potential to transfer risks arising from outlier events to the broader investor markets and have gained global traction as a means of risk transfer.

Action Plan	
Action	Responsibility
<p>Assess the potential for adopting disaster risk products, Cat bonds and parametric insurance in the Indian context.</p>	<p>CDRI—Conduct the study to assess the potential</p>



3

Resilience Cost-Benefit Analysis tool



3 Resilience Cost-Benefit Analysis tool

3.1 Overview of the RCBA tool

Need for the tool

Resilience at the project level requires incorporating structural and non-structural measures during the early stages of project planning and design. Implementing these additional resilience measures increases the overall project cost and financing needs.

To justify these additional costs, it is essential to establish a business case that compares the quantifiable benefits of investing in resilience during project design and implementation. This process involves a detailed and scientific cost-benefit analysis at the asset level. The RCBA tool has been developed to help users assess the benefits of investing in resilience and make informed decisions about integrating resilience interventions into project design, as well as to make the case for necessary additional funding for these measures.

Objective

The RCBA tool:

- Evaluates and compares the long-term financial implications of investing in disaster resilient infrastructure versus conventional infrastructure development
- Aids decision-makers in identifying the most cost-effective and sustainable approach to infrastructure development
- Quantifies the costs and benefits associated with resilience measures, including reduced disaster recovery costs and improved service continuity
- Supports informed policy and investment decisions.

What does the tool do

The RCBA tool empowers decision-makers and project managers by providing a systematic and quantitative approach to evaluating the financial implications of enhancing the resilience of various assets against identified hazards.

The tool is structured to facilitate a step-by-step process, guiding users through the critical stages of project assessment while ensuring clarity and precision in outputs.

1 Locational details and hazard data:

The tool retrieves and displays relevant hazard data specific to the selected district, thus providing a localized context for subsequent analyses. Understanding the

particular hazards in the geographical area is essential for tailoring resilience measures appropriately. The tool utilizes data from the India Meteorological Department and the Building Materials & Technology Promotion Council (BMTPC). These are the same data sources used for disaster layers in the PM Gati Shakti Master Plan.

2 Sector and asset selection:

Users can select from a range of sectors, each encompassing various asset types that may be vulnerable to hazards. The flexibility to choose specific asset types ensures that the analysis is tailored to the project's needs and characteristics.

3 Hazard intensity and damage estimation:

The tool provides standardized terminology and guidance on potential damage percentages, derived from historical data and previous events, for the chosen hazards. This quantitative approach enables users to estimate the potential impact of hazards on their assets, thereby laying the groundwork for a more informed analysis of resilience measures.

4 Financial data input and resilience options:

Users are prompted to input financial data relevant to the project, including costs associated with resilience measures. The tool allows users to select various resilience options, enabling them to explore different strategies for mitigating damage. Importantly, users can also input the expected reduction in damage ability, which is crucial for evaluating the effectiveness of the proposed resilience measures.

5 Output sheets and financial indicators:

The final output consists of comprehensive sheets detailing the financial outlay required under both baseline and resilience-enhanced scenarios. The key economic indicators are calculated, including Internal Rate of Return (IRR), net present value (NPV), benefit-cost ratio (BCR) and break-even points. These metrics provide a clear financial picture, facilitating rigorous analysis and comparison of the potential returns associated with different resilience investments.

The tool calculates the monetary difference between the costs and benefits of resilience interventions for a particular infrastructure asset, enabling an understanding of the case for resilience throughout the project lifecycle. The detailed scope is shown in Figure 20.

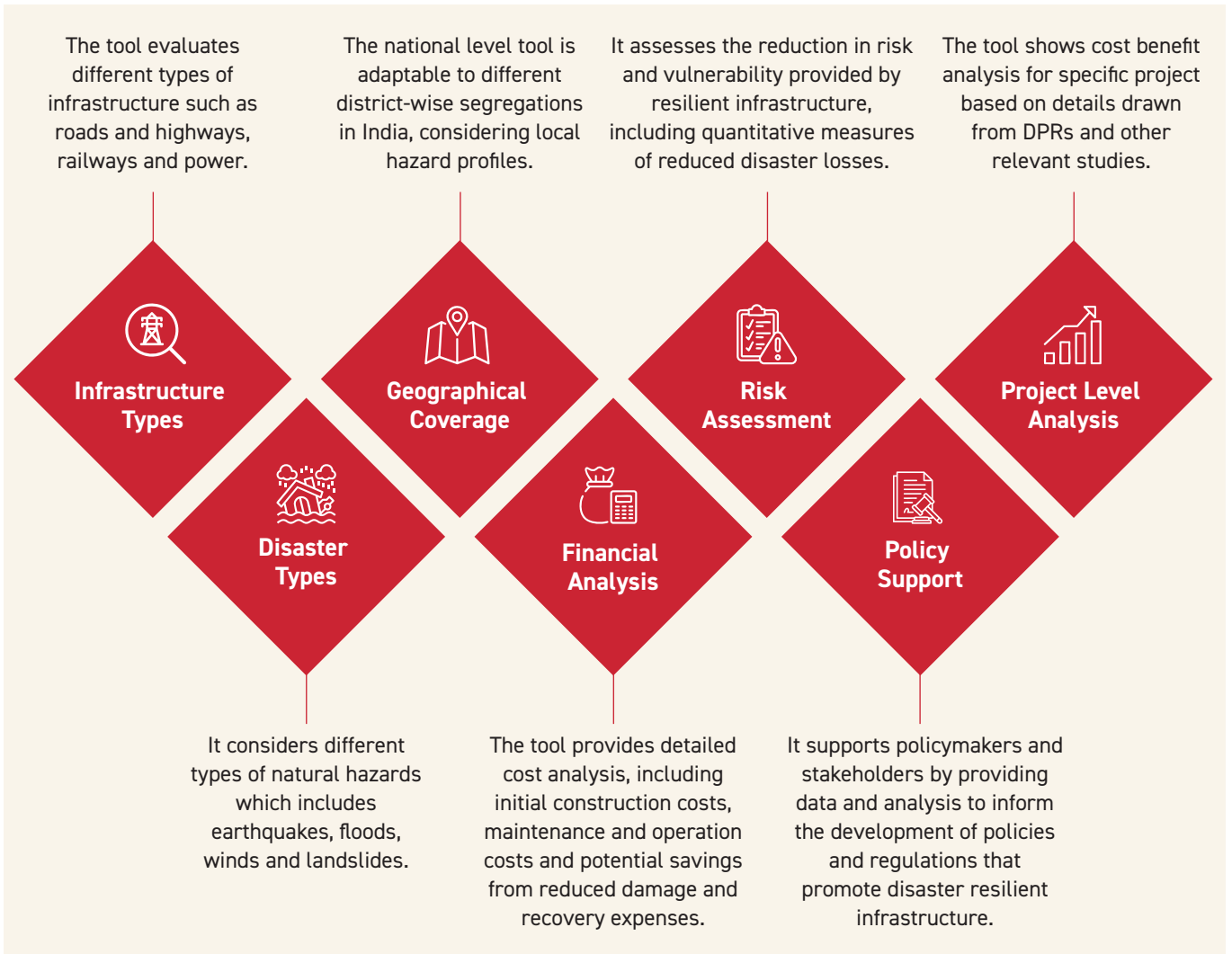
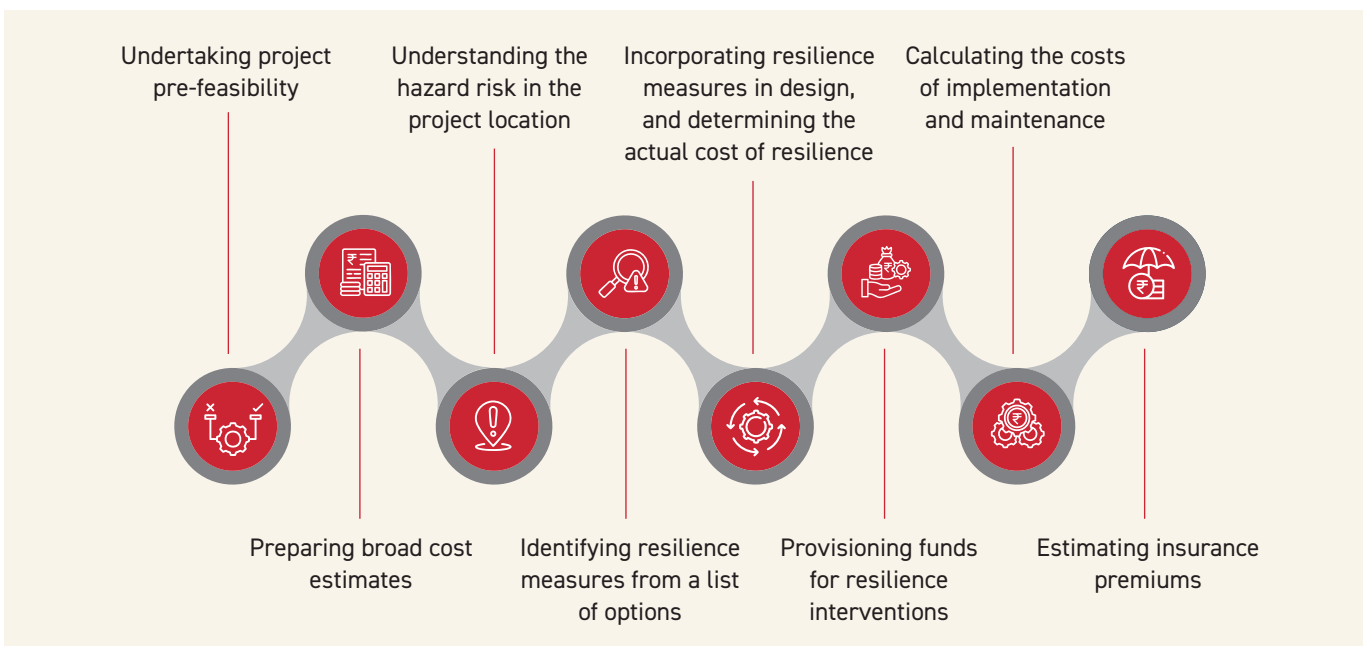
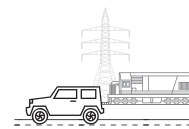


Figure 20: Scope of resilience cost-benefit analysis tool

How and who will it benefit

The tool will be beneficial in making informed decisions while:





The target users of the RCBA tool encompass a diverse range of stakeholders involved in infrastructure planning, development, policymaking and disaster management. The goal is to enhance the resiliency of infrastructure development. See Table 5.

Table 5: Target users of the RCBA tool

User	Central Ministries	Financial institutions, investors and lenders	Implementing agencies	Project developers
Use	Project planning and design preparation. Project evaluation and fund allocation.	Project evaluation for investment decisions, including enhanced due diligence for the Delta project investment.	Project conceptualization and financial feasibility. Preparing projects eligible for funds.	Investment decision-making. Incentives for incorporating resilience in design and DPRs. Checking the feasibility of various resilience options. Calculation of savings on remedying and recovery costs.
Outcome	Investing in more resilient projects. Long-term savings on recovery expenses.	Informed investment. List of resilience measures in the project.	Planning a financially feasible and resilient project.	Mainstreaming resiliency in the private sector. Resilience is incorporated at the Design and Development Review / Detailed Project Report (DPR) stage.

When should the tool be used?

Table 6 Shows when the RCBA tool can support each type of user in decision-making.

Table 6: RCBA tool applicability matrix for various project stages

User	Conceptualization	Planning	Design	Implementation	O&M
Line Ministries	Initial risk assessment	Funding need	Finance additional cost	Sanction additional cost	Approve repair needs
Implementing Agency	Initial risk assessment	Additional cost of resilience	Detailed costs	Approve additional needs	Verify repair needs
Donor/Funding Agency	Project identification	Prioritize resilience components	Investment decision	Fund additional costs	Invest in repair needs
DPR Consultant	Risk assessment	Project risks and broad costs	Include measures to estimate the cost	Identify additional measures	Estimate repair needs
Contractor	-	-	Cost estimation	Budget for additional costs	Asset health and repair needs
Lenders/ Investors	Project conceptualization	Project prioritization	Include the additional cost of resilience	Budget for additional costs	Estimate and invest in repair needs
Insurance Company	Risk assessment	Estimate coverages	Reduced risks	Estimate premium	Estimate premium

3.2 Uniqueness of the RCBA tool

It is a uniquely designed tool for assessing the benefits of resilience interventions at the project level. The salient features of the tool are as follows:

1 Project-level assessment:

It provides a project-level cost-benefit analysis, detailing each asset type and potential resilience measures.

2 Data structure:

The tool employs a scientific method to understand the hazard risk and exposure of various asset types. It features a well-designed data structure for recording damage data from natural hazards, which enables the determination of the risk profile for a particular location and asset type.

3 Damage data for selected states:

During the test runs, damage data for the selected states related to hazard events over the last ten years have been aggregated to derive reference points for hazard parameters and damageability. The exact process and data structure can be replicated for other states and used for future damage data documentation.

4 Flexible tool:

Although the reference data for hazard parameters is based on historical data, the tool is flexible in incorporating future scenarios from probabilistic models to generate future cash flows and outputs of key financial indicators.

5 Realistic tool:

It considers repair costs, operational disruption costs and the differences in premium pricing for assets incorporating resilience measures.

6 Designer's tool:

The tool is specially designed to consider the perspective of design engineers, offering flexibility for comparing various damage scenarios, selecting appropriate resilience measures, and estimating project- and site-specific costs.

3.3 Limitations of the tool

1 Does not include probabilistic disaster modelling:

The tool does not incorporate a probabilistic model to estimate the likelihood of disaster occurrences over time. The users must input the return period of a disaster based on their calculations or external data sources. This reliance on user-generated inputs can introduce variability and subjectivity into the analysis, potentially affecting the accuracy of the financial indicators produced.

2 No future distribution of events:

The future disaster scenarios and cost of retrofitting/replacement of infrastructure assets considered for RCBA will be calculated based on past data available with the line ministries.

3 No normative recommendations:

The tool is designed to provide a factual analysis without making normative recommendations. While this approach respects the autonomy of decision-makers, it may leave users seeking guidance on the implications of

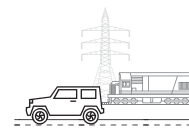
the data. Users are responsible for interpreting the outputs and determining which resilience measures to pursue, which may lead to inconsistencies in decision-making across different projects or stakeholders.

4 Static input parameters:

The tool requires users to input specific parameters, such as financial data and damage reduction estimates, without allowing for the modelling of dynamic changes over time. For example, it does not account for fluctuations in economic conditions, evolving hazard profiles, or advancements in resilience technologies. As a result, the analysis may not fully capture the potential long-term benefits or costs associated with resilience investments in a changing environment.

5 Vulnerability reduction as an output:

The tool may struggle to effectively measure vulnerability reduction due to the diverse and dynamic nature of risk factors.



6 Acute weather events considered:

While the tool provides data on specific hazards, its focus may not encompass all potential risks relevant to a given asset or location. Specific emerging hazards, localized risks, or cascading impacts from interconnected systems may not be adequately addressed. Consequently, users might overlook critical vulnerabilities when assessing the resilience of their assets.

7 Focus only on financial parameters:

The tool primarily focuses on financial metrics without consideration of the broader social, environmental and community impacts of resilience measures. Factors such

as social equity, community engagement and ecological sustainability, which are increasingly recognized as vital components of effective resilience strategies, are not included in the analyses. This limitation may hinder comprehensive decision-making that fully considers the multifaceted nature of resilience.

8 Debt service coverage ratio:

The tool's assessment of the debt service coverage ratio might not entirely reflect an entity's risk exposure or potential future financial difficulties.

Table 7: Inclusions and exclusions of the RCBA tool

Includes	Does not include
Monetary benefit of resilience	Indirect economic and financial benefits
Natural hazard impacts	Climate change impact
Acute risks	Chronic hazard risks
Deterministic model	Probabilistic model
Past hazard impacts	Future climate/hazard forecast
Uniform frequency based on past hazards	Future distribution of events
Residual damageability taken as input	Vulnerability reduction as an output
NPV, IRR, Break-even, BCR, DSCR	

3.4 Costs and benefits

Reconstruction and recovery cost:

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

$$\text{Annual reconstruction and recovery cost} = \text{Damageability (\% of asset impacted)} * \text{Total project cost (Eq. 1)}$$

$$\text{Recovery needs over the project life cycle} = \text{Frequency of hazard} * \text{Cost of repair each year (Eq. 2)}$$

Operation and maintenance costs:

O&M costs for an infrastructure asset involve various essential activities to ensure its efficient and reliable

functioning. These costs include salaries and training for personnel, routine preventive and corrective maintenance, and utilities like energy and water. Additionally, expenses for consumables, specialized equipment and contracted services for maintenance and compliance are included. Facility management, IT support, insurance and regulatory compliance further contribute to O&M costs.

Insurance premium (included under O&M costs):

This refers to the amount of money paid periodically to maintain the insurance coverage in effect.

Insurance payouts refer to the amount of money that the insurance provider, after verifying the claim, reimburses the insured for the damaged asset. It is calculated as the minimum of the amount of damage and the amount of coverage.

Revenue loss:

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

$$\text{Revenue loss} = \text{Revenue generated (per day)} * \text{Duration of hazard} * \% \text{ of asset impacted (Eq. 3)}$$

Cost of resilience:

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

$$\text{Cost of resilience \%} = (\text{Unit cost of resilience measure} * \text{Measurement of asset to be treated}) / \text{Total project cost (Eq. 4)}$$

Benefit:

The benefit or saving is calculated by summing up the differences in (Reconstruction & Recovery (R&R), O & M & Debt repayment costs) across the As-is & Resilient Scenario wherein R&R costs also include revenue losses due to disasters. (Eq. 5).

$$\text{Saving} = (\text{Reconstruction \& recovery costs} + \text{Operation \& maintenance costs} + \text{Debt Repayment costs}) \text{ As-is scenario} - (\text{Reconstruction \& recovery costs} + \text{Operation \& maintenance costs} + \text{Debt Repayment costs}) \text{ Resilient Scenario (Eq. 5)}$$

3.5 Financial indicators for investment decisions

Net Present Value (NPV):

The present value of net benefits (benefits minus costs) over the asset's lifetime.

$$\text{NPV} = \sum \frac{Ct}{(1+r)^t}$$

Internal Rate of Return (IRR):

The rate of return at which the NPV of costs and benefits breaks even.

$$0 = \text{NPV} = \sum \frac{Ct}{(1+r)^t}$$

Break-even point:

A point at which total costs and revenues are equal, i.e., there is no net loss or gain.

$$\text{Break-even point} = \frac{\text{Initial Investment}}{\text{Annual Net Cash Inflow}}$$

Benefit-cost ratio:

The ratio of the benefits of resilient infrastructure to its costs.

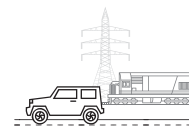
$$\text{BCR} = \frac{\text{Absolute Savings (Benefits)} = \text{Sum of Benefits across time period}}{(\text{Delta}) \text{ Project Cost or Additional Resilience investment}}$$

Debt Service Coverage Ratio:

This ratio indicates the ability of the asset's revenue to be sufficient to meet its debt service obligations. The higher the ratio, the greater the ability of the underlying asset to meet all of its debt obligations.

$$\text{Debt service coverage ratio} = \text{Net Operating Income} / \text{Debt service obligation}$$

The details of the individual dashboards for the tools, along with the underlying calculations and assumptions, are included in the RCBA tool user guide.



3.6 Testing live projects

The RCBA tool has been tested with five live NIP projects from the roads, railways and transmission sectors. Key inputs derived from detailed project reports were entered into the tool to assess the benefits of incorporating specific resilience interventions.

A defined set of shortlisting criteria was adopted to select high-value infrastructure projects from the National

Infrastructure Pipeline within the three focus sectors: roads, power and railways. The shortlisting criteria are detailed in Figure 21. Additionally, stakeholder consultations were conducted with the respective line ministries including Ministry of Road, Transport and Highways (MoRTH) and Ministry of Power, the NIP task force of DEA and relevant implementing agencies while selecting the five projects as shown in Table 8.

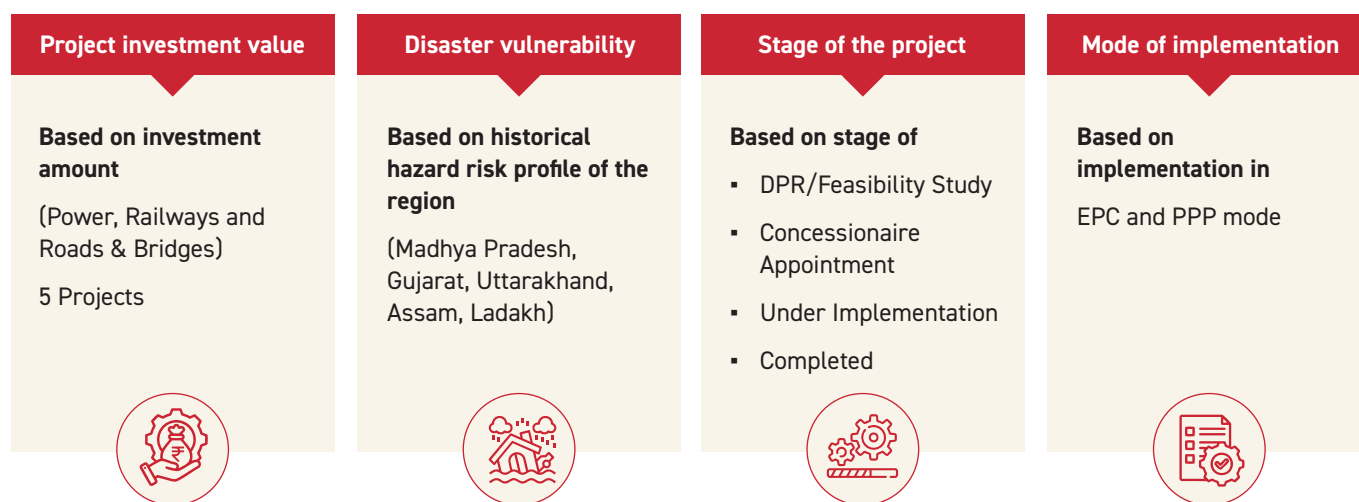


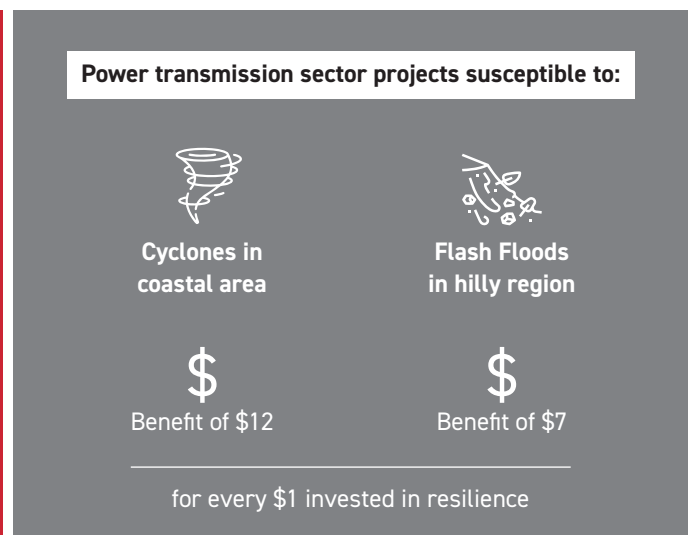
Figure 21: Project selection criteria

Table 8: List of selected NIP projects from the study

NIP project ID	Project name	Sector	State	Project Status	Implementation agency	Mode of implementation	Available documents for review
700595	4-L Silchar-Assam-Jiribam-Pkg-1	Road	Assam	Under implementation	NHIDCL	PPP	DPR, RFP, DCA, Design Report, Material Report, Technical Schedule
706446	Rudrapriya to Joshimath Package-III	Road	Uttarakhand	Under implementation	NHIDCL	EPC	DPR, RFP, DCA
705763	Indore - Budni New Railway Line	Railway	Madhya Pradesh	Under implementation	RVNL	EPC	DPR, Contract agreement, Technical Proposal, Detailed estimate document, technical details document
602612	Transmission System Associated with the Mundra Ultra Mega Power Project	Electricity transmission	Gujarat	Completed	PGCIL	PPP	DPR
606781	Strengthening of Srinagar-Leh Tr. System	Electricity transmission	Ladakh	Completed	PGCIL	EPC	DPR, Project summary document

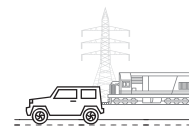
The following were the key findings from the results on the output dashboards:

NIP project ID	Project name	Sector	Resilience measure	Initial Project Cost (Cr INR)	Resilience Cost (Cr INR)	Absolute lifetime saving (Cr INR)	Benefit-Cost Ratio
706446	Rudraprayag to Joshimath Package-III	Road	Landslide zone treatment, Breast wall, Retaining wall, Slope protection	387	31	228	7
700595	4-L Silchar-Assam-Jiribam-Pkg-1	Road	Drainage & Protection, Slope protection, breast wall, Retaining wall	617	28	218	8
705763	Indore - Budni New Railway Line	Railway	Embankment	7,474	122	233	2
602612	Transmission System Associated with the Mundra Ultra Mega Power Project	Electricity transmission	Underground cables in vulnerable stretches	4,546	573	6,589	12
606781	Strengthening of Srinagar-Leh Tr. System	Electricity transmission	High tension low sag conductors, Underground transmission corridor	1,033	83	546	7



Application of RCBA tool across five infrastructure projects demonstrated the Financial value of investing in resilience. In all the test cases, the estimated benefits of incorporating resilience measures outweighed the associated costs. For road sector projects, a benefit of \$8 was calculated for every \$ invested in flood resilience, and a benefit of \$7 was calculated for every \$ invested in landslide resilience.

Similarly, for power transmission sector projects, a benefit of \$12 for every \$1 invested in cyclone resilience and a benefit of \$7 for every \$1 invested in flash flood resilience were calculated, proving the utility of the tool for understanding the benefits of incorporating resilience measures into infrastructure projects. The detailed findings from the RCBA tool in the individual projects are included in Annexure 7.



Economic Benefits:

The benefits mentioned above includes only the Recovery and Reconstruction costs avoided, this number is likely to be much higher if we factor for Revenue losses avoided and

other economic benefits resulting from the resilience measures. The economic benefits of resilience could include service disruptions and human costs avoided along with other co-benefits such as mitigation, biodiversity conservation and sustainable development in most cases.

3.7 Roadmap to mainstream the RCBA tool

The tool requires the participation of all stakeholders to achieve its goals of sophistication and accuracy. The project testing the RCBA tool has yielded positive results. The actual benefit-cost ratios will be much higher if indirect economic benefits and other resilience co-benefits are considered. The tool is dynamic and will produce more accurate results when loaded with more asset-specific data on past impacts.

Suggested roadmap for the RCBA tool:

Phase I: The tool will be hosted on a web-based platform, with fine-tuning conducted through beta testing. Inputs from a wider set of project design documents will be collected, including ground-level impact-specific data on asset classes, additional intervention dropdowns based on the resilience taxonomy, and budgeting based on unit prices.

Phase II: The tool will be scaled up to include functionalities for other infrastructure sub-sectors, such as buildings, urban sub-sectors (including water, solid waste management, urban transport, etc.), power (including power generation and renewable energy assets) and other critical infrastructure. This phase will also enhance accessible hazard impact data for a broader range of natural hazards and integrate the tool with a granular hazard catalogue, specifically the next version of CDRI's (probabilistic disaster risk and assessment platform) GIRI, i.e., GIRI 2.0.

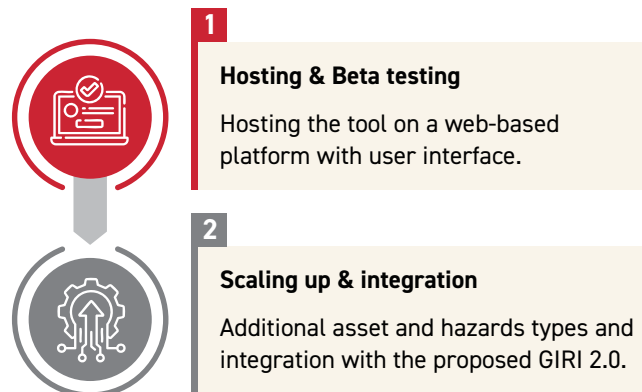


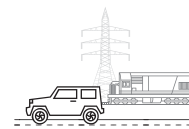
Figure 22: Roadmap for Resilience Cost Benefit Analysis (RCBA) tool

The Excel-based RCBA tool will be made available to line ministries, authorities and relevant stakeholders to test-run their projects with appropriate data. It is accompanied by a detailed user guide to help navigate and use the tool to its full potential.



4

Toolkit for Infrastructure Resilience



4

Toolkit for Infrastructure Resilience

4.1 The Content of the Toolkit

The toolkit for disaster resilience includes the following:

List of resilience measures

List 1: List of resilience measures for bidding and contractual documents

List 2: List of design options for asset resilience

Guidance documents

Guidance Document 1: Project Identification and Appraisal Guidance Document for Line Ministries, Including Disaster Risk Considerations

Guidance document 2: Project proposal preparation guidance document for potential bidders to include disaster resilience goals

A snapshot of the key features of the resilience toolkit is shown below.





Disaster resilience toolkit	List of resilience measures		Guidance document for evaluation and project development	
				
Content	List of resilience measures for bidding & contractual documents	List of design option for asset resilience	Incorporating disaster risk considerations in project identification and appraisal	To guide them in preparing project proposals that include disaster resilience goals
1 Owner	Line ministries and DEA	Line ministries & Technical bodies	Line ministries and DEA	DEA, Line ministries and Potential bidders
2 User	Line ministries, DEA, Implementing agencies, potential bidders	Line ministries, Implementing agencies, potential bidders	Line ministries	Potential bidders
3 Applicability	Project and bid evaluation , project funding	Asset design and Cost Benefit Analysis	Navigate the toolkit Locations in standard documents to incorporate resilience	Guidelines on preparing disaster resilience proposal
4 Outcome	Disaster risk management, resilient projects, more resilient projects	Cost benefit of resilience, more resilient assets	Disaster resilient standard agreements with defined responsibility sharing	Winning bids achieving resilience goals in infrastructure project. Increased eligibility for funding

Figure 23: Snapshot of key features of the resilience toolkit

4.2 List of Resilience Measures

List 1: List of resilience measures for bidding and contractual documents

List 2: List of design options for asset resilience

Purpose of the List

The list will support line ministries and private sector stakeholders in incorporating climate resilience and disaster risk mitigation goals by modifying standardized bidding and contractual documents for EPC/PPP model agreements.



Figure 24: Overview of 'List of Resilience Measures'

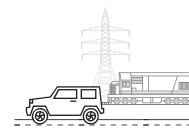
The most prevalently used standard documents for the road, railway and power sectors:

The Standard EPC Agreement for National Highways and Centrally Sponsored Road Works, the Standard EPC document for railway tracks and the Standard Bidding Documents (SBDs) for the procurement of ISTS through the TBCB process were identified and analysed, focusing on disaster resilience considerations. A literature review helped gather best practices regarding the existing clauses and gaps identified within the standard documents. Suggestions on incorporating resilience have been supported by the national and international best practices as

references. By leveraging resilience themes, existing gaps and best practices have been identified that can be integrated into standardised bidding and contractual documents to enhance disaster resilience.

List of Resilience Measures for Bidding and Contractual Documents

Based on the appraisal of standard agreements and contractual documents conducted for roads, railways and power sectors, a list of modifications to enhance disaster resilience considerations and mainstream them within the infrastructure project lifecycle has been prepared.



Clause 10.1.6 – Appointment of Road Safety Consultant under Article 10

Coverage

This clause provides recommendations for the road safety consultant to be incorporated into the project's design. If any work required by the road safety consultant falls beyond the prescribed scope of the contractor, the contractor shall seek a change in scope.

Issue

As the project's design is the contractor's responsibility, the design should not only adhere to design standards but also incorporate all necessary safety features, including disaster resilience measures/attributes. Therefore, the necessity of safety incorporation in project implementation should not be enumerated as a reason for a 'change of scope'.

Suggestion

An appropriate road design should address all of these issues, including hazard risk mitigation. If the safety consultant highlights any gaps in the road design that make the asset unsafe and suggests mitigations to close the gaps in the design, it should not cause any change in the project's scope. Therefore, disaster resilience measures/attributes should be part of the overall scope of work and design.

Figure 25: Snapshot of List of resilience considerations in roads sector

Key suggested modifications in the Standard Bidding & Contractual Documents:

■ Appoint resilience experts at all project stages:

Resilience experts should be appointed to ensure regular monitoring and assessment of infrastructure in terms of safety and disaster resilience, thereby mitigating potential failures and hazard damage.

■ Enforce stringent qualification criteria:

Stringent and resilience-focused qualification criteria should be enforced for experts within the team of detailed project report (DPR) consultants, as well as contractors, to ensure high-quality outcomes.

■ Mention compliance with disaster resilience:

A provision should be made with a scope that clearly states the requirement to ensure compliance with disaster resilience measures.

■ Integrate a damage clause:

An explicit damage clause should be integrated to address any negligence or failure resulting from the contractor's non-compliance.

■ Do not consider modifications due to defaults in the designs as a change of scope:

Any modifications or suggestions arising from defaults, deficiencies, or shortcomings in the designs and works shall not be considered a change of scope.

■ Include mitigation measures:

Appropriate infrastructure designs must ideally address hazard risk mitigation measures to strengthen resilience.

■ Incorporate key performance indicators in designs:

A key performance indicator should be incorporated in the documents, mandating site visits at random or regular intervals and testing of disaster resilience measures to ensure compliance.

■ Include penalty and remedy for non-compliance:

A penalty or damages for non-compliance with resilience measures should be explicitly stated in the standard documents, along with the repercussions and proper remedy.

■ Include non-compliance in the event of default:

The non-compliance of disaster resilience measures should be introduced as an event of default.

■ Develop a detailed schedule for safety and disaster resilience:

A comprehensive schedule addressing safety and disaster resilience measures should be developed and implemented.

■ Disaster resilience in the scope of work:

The scope of work should mention and include disaster resilient features in the design and construction.

■ Cover disaster risks through insurance:

Specific insurance provisions should be included to cover residual risk due to natural hazards.

List of Design Options for Asset Resilience

Similarly, a List of Design Options has also been provided, which is a non-exhaustive list for reference of DPR consultants & project developers. These Design Options contain a large number of engineering solutions specific to infrastructure sectors, aimed at enhancing resilience against various hazards.

Design options for increasing project resilience in road sector

Design and technical aspects		
Hazard	Measure	References
Landslide zones	Measures for Unstable Slope	
	<p>1. Modification of Slope Geometry</p> <ul style="list-style-type: none"> i. Removing material from the area driving the landslide (with possible substitution by lightweight fill) ii. Adding material to the area maintaining stability (counter-weight berm or fill) iii. Reducing general slope angle <hr/> <p>2. Drainage</p> <ul style="list-style-type: none"> i. Surface drains to divert water from flowing onto the slide area (collecting ditches and pipes) ii. Shallow/deep trench drains filled with free draining geomaterials (coarse granular fills and geosynthetics) iii. Buttress counter forts of coarse-grained materials (hydrological effect) iv. Vertical (small diameter) boreholes with pumping or self-draining v. Vertical (large diameter) wells with gravity draining vi. Sub-horizontal or sub-vertical boreholes vii. Drainage tunnels, galleries or adits viii. Vacuum dewatering ix. Drainage by siphoning x. Electro-osmotic dewatering xi. Vegetation planting (hydrological effect) 	<p>Engineering Guidelines on Landslide Mitigation Measures for Indian Roads, Indian Roads Congress (IRC), 2015</p> <p>Guidelines on Flood Disaster Mitigation for Highway Engineers, Indian Roads Congress (IRC), 2018</p> <p>Hill Road Manual (First Revision), Indian Roads Congress (IRC), 2023</p>

Figure 26: Snapshot of 'List of Design Options'

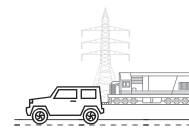
4.3 Guidance documents

1. Guidance document for line ministries:

This guidance document supports the line ministries of roads, power and railways in incorporating disaster and climate resilience aspects into the standardized bidding and contractual documents of EPC (Engineering, Procurement and Construction) and PPP (Public-Private Partnership) model agreements. The guidance document will help line ministries navigate the list of resilience measures and identify any gaps in the existing contractual clauses related to resilience.

2. Guidance document for potential bidders:

This guidance document is designed to assist potential bidders in preparing project proposals integrating disaster resilience goals, thereby enhancing the value and competitiveness of their bids. By following this guidance document, potential bidders will be well-positioned to develop proposals that not only meet the required standards but also make meaningful contributions to building more resilient infrastructure.



Applicability		Documents to be referred during the project stages			
Stage	User	Guidance documents for line ministries and bidders	Engineering design options for asset resilience	RCBA tool and user guide	Bidding and contracts checklist for resilience measures
Planning	Line ministries	■	■		
	Potential bidders				
Design	Line ministries	■	■	■	■
	Potential bidders	■		■	■
Implementation	Line ministries	■		■	■
	Potential bidders	■		■	■
Operation & maintenance	Line ministries	■			■
	Potential bidders	■			■

Figure 27: Usage flow of the toolkit

A checklist has been systematically structured for ministries to identify and address gaps in the existing contractual clauses related to resilience. The steps outlined in the Figure

31 provides an overview of how to navigate the checklist (For more details, refer Guidance document for Line Ministries and Potential Bidders):

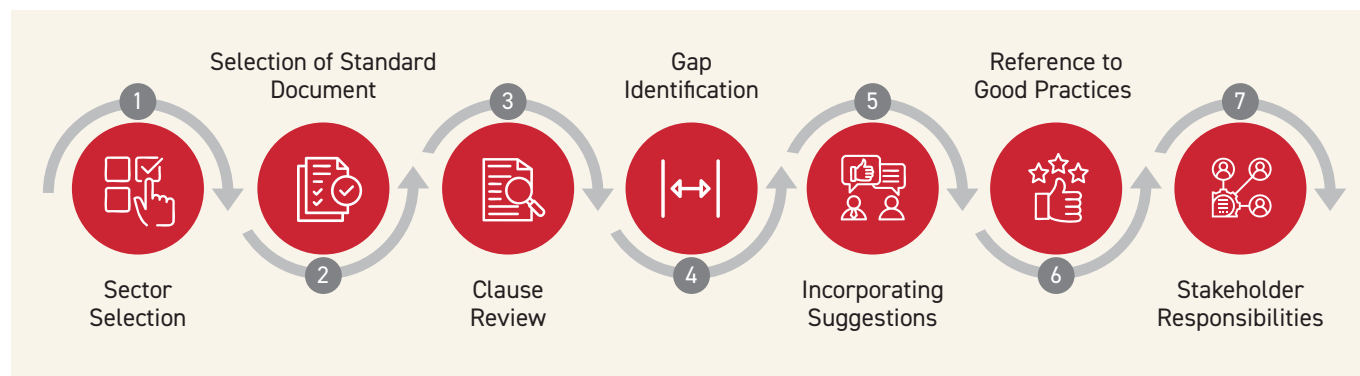


Figure 28: Steps to navigate the checklist

4.4 Way Forward

The toolkit will be a standalone document that will be shared with relevant stakeholders to help them incorporate resilience into infrastructure assets and related processes. To mainstream resilience in infrastructure, further phases will involve the development of the toolkit for a broader

range of asset types and implementation mechanisms. Increased involvement and efforts from line ministries will be required to make the suggested modifications in the model documents and enforce their applications.

Phase I:

Uptake:

Assist the incorporation of suggested modifications in the standard bidding documents and model concessionaire agreements by line ministries.



Phase II:

Deep Dive:

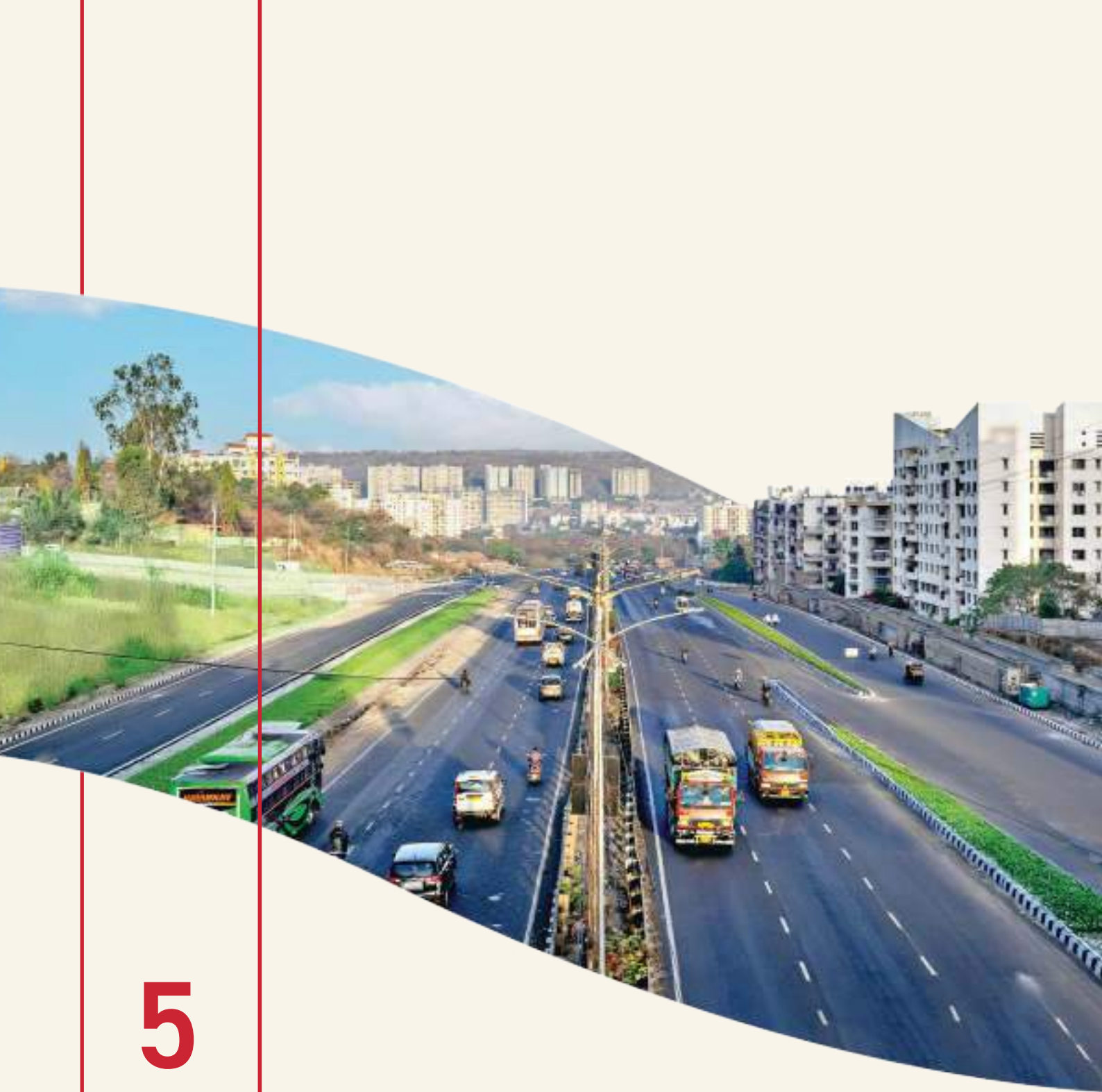
Undertake appraisal of other relevant documents across the three sectors for various project implementation modalities, including contractual agreements, O&M manuals and other SoPs, to ensure overall sectoral resilience.



Phase III:

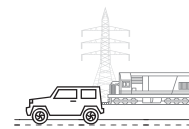
Expand:

Undertake appraisal of Standard Contractual Documents and other relevant documents from other infrastructure sectors.



5

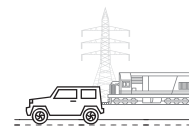
Glossary



5 Glossary

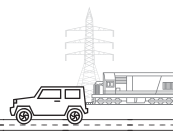
Term	Definition
Adaptability	Adaptability in infrastructure refers to the ability of infrastructure systems to adjust and respond to changing conditions and needs in an efficient manner. This includes the capacity to modify, repurpose or upgrade infrastructure with minimal cost and effort. Adaptable infrastructure can be quickly constructed, easily modified for different uses and efficiently relocated or recycled when no longer needed (GCA Report, 2019).
Average Annual Loss	Average Annual Loss (AAL) is a measure of future losses calculated annually over a long term, which is derived from probabilistic risk models. It provides insight into potential damage and loss to infrastructure assets (CDRI, 2023).
Benefit-Cost Ratio	The benefit-cost ratio (BCR) is a metric used in cost-benefit analysis to summarize the overall value for money of a project or proposal. It is calculated by dividing the total expected benefits of a project by its total expected costs. A BCR greater than 1.0 indicates that the project's benefits outweigh its costs, suggesting it is a worthwhile investment (Investopedia, 2024).
Break-even Point	In cost-benefit analysis, the break-even point is the point at which total costs and total revenues are equal, meaning there is no net loss or gain. This is a critical metric for determining the minimum performance required for a project or investment to be viable (SBA, 2024).
Building Back Better	Building Back Better (BBB) is a strategy designed to mitigate the risks to people and communities in the aftermath of future disasters and shocks. It involves integrating disaster risk reduction measures into the restoration of physical infrastructure, societal systems and the revitalization of livelihoods, economies and the environment. The goal is to enhance resilience and reduce vulnerability to future disasters (UNISDR, 2017).
Building Information Modelling	Building Information Modelling (BIM) is a collaborative process that involves the generation and management of digital representations of a building's physical and functional characteristics, as well as those of other physical assets. It utilizes a shared digital representation to facilitate design, construction and operational processes, providing a reliable basis for decisions throughout the lifecycle of a built asset (Institution of Structural Engineers BIM Panel, 2021).
Cost of Resilience	The cost of resilience, considering infrastructure, refers to the expenses involved in enhancing and maintaining the ability of infrastructure systems to withstand, adapt to and recover from adverse events. This includes investments in design, construction and maintenance practices that improve the durability and flexibility of infrastructure, ensuring it can continue to function during and after disruptions (UNDRR, 2023).
Cost-Benefit Analysis	Cost-benefit analysis (CBA) is a process used to evaluate the total expected costs against the total expected benefits of a project or decision, determining its feasibility (Investopedia, 2024).
Critical Infrastructure	Critical infrastructure is the physical structures, facilities, networks and other assets that provide services essential to the social and economic functioning of a community or society. Examples of critical infrastructure sectors include the transport sector, energy sector, healthcare sector and water sector, to name a few (UNDRR, 2024).
Direct Disaster Losses	Direct disaster losses refer to quantifiable losses that can be directly measured, such as the number of people killed and the damage to buildings, infrastructure and natural resources (GFDRR, 2014).

Term	Definition
Disaster	A severe disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic, and environmental losses and impacts (UNDRR, 2015).
Disaster Resilient Infrastructure	Infrastructure systems and networks, their components and assets and the services they provide must be able to resist and absorb disaster impacts, maintain adequate levels of service continuity during crises and swiftly recover in a manner that reduces or prevents future risks. (Lexicon, CDRI)
Disaster Risk Financing	Disaster risk financing refers to financial strategies and instruments designed to manage the economic impacts of natural hazards and increase the financial resilience of countries to disasters. This approach involves pre-arranged financial mechanisms, such as insurance, catastrophe bonds, contingency budgets and contingent loans, to cover the costs of preparation, response, recovery and reconstruction (WB-GFDRR, 2016).
Disaster Risk Reduction	The policy objective of disaster risk management is to prevent new disasters and reduce existing ones, while managing residual risk, all of which contribute to strengthening resilience and, therefore, achieving sustainable development (UNDRR, 2015).
Indirect Disaster Losses	Indirect disaster losses include declines in output or revenue and an impact on the well-being of people, generally arising from disruptions to the flow of goods and services as a result of a disaster (GFDRR, 2014).
Infrastructure Resilience	Infrastructure Resilience is the timely and efficient prevention, absorption, recovery, adaptation and transformation of the national infrastructure's essential structures and functions, which have been exposed to hazards. Implementing resilience across all phases of disruption should be achieved through collaborative risk and uncertainty management, multi-hazard assessment and methods that acknowledge the systemic nature of national infrastructure (UNDRR, 2022).
Interconnectedness	Interconnectedness in the context of resilient infrastructure refers to the degree to which different infrastructure systems and components are linked and dependent on each other (UNDRR, 2022).
Initial Construction Costs	The initial construction cost comprises detailed estimates of the initial costs for building disaster resilient infrastructure versus conventional infrastructure (Wang, 2018).
Interdependency	Interdependency in the context of resilient infrastructure refers to the mutual reliance between different infrastructure systems and sectors. It highlights how the functioning of one system can significantly impact the performance and resilience of another (UNDRR, 2022).
Internal Rate of Return	The rate of return at which the net present value of costs and benefits breaks even (AFP, 2024).
Maintenance and Operation Costs	Ongoing costs associated with maintaining and operating both types of infrastructure (ATAP, 2022).
Natural Hazard	A natural hazard is defined as a natural event that has the potential to cause harm to humans, property and the environment (FEMA, 2024).
Codal Minimums	Minimum parameters that are mandated by the Design code/standard.



Term	Definition
Hazard, Risk and Vulnerability Analysis	Hazard, Risk and Vulnerability Analysis (HRVA) is a systematic process that identifies potential hazards, evaluates the risks they pose and assesses vulnerabilities that could exacerbate their impacts, thereby enabling communities to make informed decisions to mitigate risks and enhance preparedness (Emergency Program Act, Government of British Columbia, 2021).
Hazard Thresholds	The extent & level of hazard intensity, which, based on the past occurrence data, could be considered foreseeable and thus could be excluded from the definition of Force Majeure.
CAT Bonds	CAT Bonds, or Catastrophe Bonds, are financial instruments used to transfer specific risks associated with catastrophic events, such as natural disasters, from insurance companies to investors (Investopedia).
Net Present Value	The present value of net benefits (benefits minus costs) over the infrastructure's lifetime (AFP, 2024).
Parametric Insurance	Parametric insurance, also known as index-based insurance, is a pre-agreed payout when a specific event occurs based on predefined parameters or indices. Unlike traditional insurance, which compensates for actual losses incurred, parametric insurance pays out based on the occurrence and severity of a triggering event (Swiss Re, 2023).
Preparedness	Preparedness in the context of disasters is defined as a continuous cycle of planning, organizing, training, equipping, exercising, evaluating and taking corrective action to ensure effective coordination during incident response (FEMA, 2024).
Prevention	Prevention in the context of disasters refers to actions taken to avoid the occurrence of a disaster or to reduce its impact. This includes activities such as planning, public information and warning, operational coordination and intelligence sharing (FEMA, 2016).
Public Private Partnership (PPP)	A public-private partnership (PPP) is a long-term contract between a private party and a government entity for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance (WB, 2022).
Recovery Cost	Savings in post-disaster recovery expenses due to improved resilience (UNDRR, 2024).
Reduced Damage Costs	Estimated savings from reduced damage and repair costs in the event of a disaster (UNISDR, 2007).
Redundancy	Redundancy is the inclusion of extra components or systems that can take over in case the primary system fails. This ensures continuous operation and enhances the reliability and resilience of critical infrastructure (UNDRR, 2022).
Resourcefulness	Resourcefulness in the context of resilient infrastructure refers to the ability to identify problems, establish priorities and mobilize resources when conditions exist that threaten to disrupt some element, system, or community (UNDRR, 2022).
Resilience	The ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNDRR, 2024).

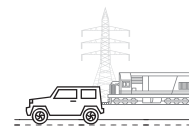
Term	Definition
Risk	Risk of disasters may be defined as the potential loss of life, injury, or destruction or damage to assets that could occur to a system, society, or community within a specific period, determined probabilistically as a function of hazard, exposure, vulnerability and capacity (UNDRR, 2024).
Risk Assessment	A qualitative or quantitative approach to determine the nature and extent of disaster risk by analyzing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend (UNDRR, 2024).
Risk Mitigation	The lessening or minimizing of the adverse impacts of a hazardous event (UNDRR, 2024).
Risk Pooling	A risk management strategy that involves combining multiple risks into a single pool to reduce the overall risk for each entity. This approach helps to spread the financial impact of risks across all members of the pool, thereby minimizing the burden on any single member (UNDRR, 2024).
Robustness	Robustness in the context of resilient infrastructure refers to the ability of systems, structures and components to withstand and perform under a wide range of conditions without significant degradation or failure (UNDRR, 2022).
Systems Thinking	Systems thinking is an approach to problem-solving that views problems as parts of an overall system rather than in isolation. This method emphasizes understanding the interrelationships and interactions between different components of a system to address complex issues effectively (NIH, 2023).
Tariff-Based Competitive Bidding	Tariff-based competitive bidding (TBCB) is a procurement process used to encourage competition and transparency in the development of infrastructure projects, particularly in the energy sector. According to the guidelines issued by the Ministry of Power in India, TBCB aims to promote competitive procurement of transmission services, encourage private investment and ensure fairness in the procurement process (MoP, 2021).
Viability Gap Funding	Viability gap funding (VGF) refers to financial support provided to projects that are economically justified but not financially viable on their own. This funding is typically offered as a grant to make such projects attractive to private investors. The goal is to bridge the gap between the project's cost and the revenue it can generate, ensuring its completion and operation (DEA, 2020).
Vulnerability	The conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an individual, a community, assets, or systems to the impacts of hazards (UNDRR, 2024).





6

Annexures



6 Annexures

Annexure 1

International good practices on mainstreaming disaster resilience aspects into standard documents and contractual agreements

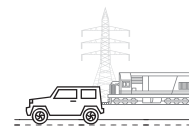
To understand the scope of incorporating resilience measures within infrastructure projects a literature review was conducted, listing some successful good practices across various countries. These good practices can be

utilized as a reference for incorporating disaster resilience into standard documents and contractual agreements.

Table 9: International Approaches to Incorporating Climate Resilience in Infrastructure Contracts

International Examples	Measures incorporated
Australia	
Melbourne Metro Tunnel - Tunnel and Station PPP Project Agreement	The private partner must address sustainability requirements within all relevant Design Packages at each Design Stage and is required to produce a Sustainable Design Report at each design stage (7.18). The output specifications include climate change adaptation and mitigation requirements: The design that “must include measures for all high and extreme climate change risks to ensure the infrastructure, Stations and precincts are resilient to the projected impacts of a changing climate over the relevant asset’s Design Life.”
The Partnerships Victoria standard Project Deed is considered the market standard PPP position as drafted by the procuring authority in Victoria	It provides the list of relevant events to be considered under force majeure. The events include: <ul style="list-style-type: none"> ■ Earthquake, natural hazards, bushfire, landslide, seismic activity, tsunami or mudslide. ■ Winds, including sustained surface winds over 118 kilometres per hour (km/h) and gusts over 165 km/h during the development phase, and sustained surface winds over 118 km/h and gusts over 225 km/h during the operations phase (as recorded by the Bureau of Meteorology, Melbourne). ■ A flood that might, at the date of the relevant deed, be expected to occur no more frequently than once in every 100 years.
United States	
Facility Concession Agreement between the Texas Department of Transportation and the SH 130 Concession Company	Construction must meet the requirements outlined in the Technical Requirements (7.2.1. Facility Concession Agreement). 12.3 (no. 6) of the Technical Requirements specifies, for example, the Drainage Design Criteria as follows: ‘all drainage structures, storm systems and outfalls shall be evaluated for the 100-year storm event’.
OECD countries	
Countries like Australia and the United Kingdom treat weather events separately from ‘force majeure’	<p>A central practical issue is the extent to which climate change impacts are covered by relief, compensation or ‘force majeure’ clauses in PPP contracts. These clauses partially or entirely indemnify the concessionaire against risks that are exogenous, unpredictable, or unforeseeable. In practice, risks covered by these clauses represent potential financial liabilities held by the government.</p> <p>In the United Kingdom, concessionaires are not eligible for financial compensation following hydro-meteorological events. The risks from climate change are uncertain, but in some cases, they are now foreseeable based on the available scientific evidence.</p>

International Examples	Measures incorporated
Japan	
Resilient Infrastructure Public-Private Partnerships (PPPs): Contracts and Procurement - Japan	<p>Defining Force Majeure: The 'Guidelines for Contract: Points to Consider for PPP Project Contracts' released by Japan's PPP/PFI Promotion Office defines force majeure as follows: "a disaster that is generated externally without any relation to the actions, such as an agreement, made by the entities and cannot be prevented even if the generally required precautions and preventive actions are taken." More specifically, it 'is not attributable to the contracting authority and the private operator; in particular, a storm, torrential rain, flood, high tide, landslide, cave-in, lightning strike, earthquake, fire, generation of poisonous gas, etc., which fall under disasters, as well as a disturbance, riot, war and act of terrorism, which fall under man-made disasters.'</p>
Sendai City - Iterative Processes to Enhance Understanding and Risk Sharing between the Public and Private Sectors	<p>In the chronological review of cases in Sendai, force majeure events were listed as examples in the earlier projects and defined as foreseen phenomena under normal circumstances for which no concerned entity was responsible. Based on lessons learned from the 2005 Miyagi Earthquake, the 2011 Great East Japan Earthquake and other disasters, force majeure provisions specified the seismic intensity, and by considering historical disaster damages, Sendai City also added a numerical standard that regarded an event of at least a certain level as a force majeure event. Furthermore, there has been a past controversy regarding the distinction between damage caused by a private operator due to facility defects and damage caused by a natural hazard. Sendai City clarified in the PPP contracts that damage caused by a natural hazard will be judged based on whether similar buildings in the vicinity suffered identical damage. Such clarification of force majeure provisions resulted in:</p> <ul style="list-style-type: none"> ■ Fewer questions and uncertainty on the DRM responsibility of the public and private sectors ■ The private sector considers disaster risks during the project planning stage ■ Prompt emergency responses by the private sector <p>Because Japan is prone to disasters, the public sector has typically borne disaster risks, which has partly contributed to the development of public-private partnership (PPP) markets in Japan. However, as both the public and private entities accumulate PPP experience, disaster risks that the private sector can reasonably manage have been transferred to the private sector, depending on the project type and characteristics.</p>
Concessionaire Screening Using DRM Evaluation Criteria in Airport PPP Projects - Evaluation of a Concessionaire for Kansai International	<p>A key point of the screening of concessionaires was that, although it was not restricted to disasters, it provided a positive evaluation for private operators that secured stable and reliable operations by allocating sufficient funding for Disaster Risk Management (DRM) and reserve funding for airport operations. It also provided a positive evaluation of private operators that prioritized safe and secure airport operations by executing maintenance and renovation investments in a preventive and systematic manner.</p>
Colombia	
Colombia's 4th Generation Road Concession PPP	<p>The La Niña floods of 2010-2011 resulted in economic losses estimated at \$6 billion, of which 38 percent stemmed from damage to infrastructure. Roads under concession suffered damage of \$88 million, leading to disputes between road concessionaires and the government over which party was responsible for covering these damages. In response, the national infrastructure agency enhanced and clarified insurance requirements with technical support from the World Bank. The contract for the latest tranche of new roads allocates climate risks to the concessionaires on the basis that they will be best placed to manage those risks. Concessionaires must hold sufficient insurance to cover their expected Probable Maximum Loss. The risk of insurance premiums increasing in future due to climate change rests with the private sector.</p>



Annexure 2

Details on critical infrastructure resilience frameworks

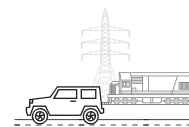
Through a literature review, 10 widely utilized critical infrastructure resilience frameworks were identified and analyzed. These frameworks can be considered comprehensive guides for integrating disaster resilience

measures throughout the entire infrastructure project lifecycle, from planning and design to operation and maintenance.

Table 10: Comparative Analysis of Infrastructure Resilience Frameworks

Frameworks	Relevant critical infrastructure (CI) coverage	Hazard coverage	Level	Key features	Use cases
Resilience Measurement Index (2013)	All CI	Natural hazards (earthquakes, hurricanes, floods, tornadoes and extreme weather events) and technological hazards (infrastructure failures, cyber-attacks)	Project, system	<ul style="list-style-type: none"> Assesses resilience against diverse natural and artificial threats Uses metrics like quality, failure probability and post-event functionality to evaluate infrastructure resilience Assists in risk management, disaster response and business continuity planning 	<ul style="list-style-type: none"> Aids in designing and maintaining Identifies and mitigates vulnerabilities Guides strategies to minimize disruption and recovery time
Measuring critical infrastructure resilience (ETH Zurich)	All CI	Natural hazards, cyber-attacks and terrorist threats	Project, system	<p>Considers pre- and post-disaster resilience indicators to assess the resilience of infrastructure.</p> <ul style="list-style-type: none"> A-priori indicators (e.g. probability of failure; Quality of infrastructure; Pre-event functionality of the infrastructure) Post-hoc indicators e.g. (systems failure; Post event functionality; post-event damage assessment; Recovery time post event; Recovery/loss ratio) 	
Critical Infrastructure Resilience Index (CIRI)	All CI	All hazards	Project, system, organizational, country/ regional levels	<ul style="list-style-type: none"> Comprehensive coverage of indicators under different crisis management phases of the cycle: Risk Assessment, Prevention, Preparedness, Warning, Response, Recovery and Learning Key focus on early warning indicators is one of the distinct features 	

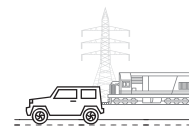
Frameworks	Relevant critical infrastructure (CI) coverage	Hazard coverage	Level	Key features	Use cases
Resilience Rating System	Transportation, Energy, Water Supply & Sanitation	Natural hazards and extreme weather events	Project, Country and Regional	<ul style="list-style-type: none"> ■ Key focus on two dimensions: Resilience of the Project & Resilience through the Project ■ The dimension 'Resilience through the project' and the parameters considered are some of its unique features. This dimension focuses on the impact the project is creating at various scales in terms of strengthening resilience. 	<ul style="list-style-type: none"> ■ Informs decisions to ensure climate-resilient investments ■ Standardizes project evaluation to shape resilience policies ■ Identifies and mitigates infrastructure vulnerabilities ■ Tracks and reports project resilience for transparency and accountability
ARUP-Energy Resilience Framework	Energy	All hazards	Project, Country and Regional	<p>The framework has a total of 11 goals and 66 indicators under the three dimensions to assess resilience:</p> <ul style="list-style-type: none"> ■ Leadership and strategy ■ Economy and society ■ Infrastructure and ecosystem <p>It is more focused on the commercial perspective.</p>	<ul style="list-style-type: none"> ■ Guides the development of energy systems that are robust against disruptions ■ Informs policies to enhance the resilience of energy systems against future challenges and threats ■ Aids investors in making informed decisions to support resilient energy projects
Infrastructure Resilience Planning Framework	Communication, Transport, Energy	Natural hazards, technological hazards and artificial hazards	Project, System, National/ Regional	<p>It highlights the co-benefits to the community through critical infrastructure resilience. It includes four steps:</p> <ul style="list-style-type: none"> ■ Identify the potential impacts of hazards on normalcy and service delivery ■ Prepare to withstand, adapt and mitigate evolving threats due to hazards ■ Integrate infrastructure resiliency into planning and implementation, financing and decision making ■ Recover quickly and bounce back to normalcy 	<ul style="list-style-type: none"> ■ Equips stakeholders to adapt to emerging threats ■ Embeds resilience into planning and investments ■ Facilitates rapid recovery from infrastructure disruptions



Frameworks	Relevant critical infrastructure (CI) coverage	Hazard coverage	Level	Key features	Use cases
EU – Circle Resilience Framework	Energy, Industry, Water, Transportation, Information and Communication Technology	Climate-related hazards (e.g. extreme weather events, rising temperature)	Project, System, National/Regional	<p>This resilience framework adopts the following four layers for resilience assessment:</p> <ul style="list-style-type: none"> Climate hazard and climate hazard parameters Critical infrastructure, their networks and interdependencies Risks and impacts of climate change Capacity of critical infrastructure to withstand/respond/recover/strengthen resilience 	<ul style="list-style-type: none"> Evaluates climate impacts on critical infrastructure Aids in planning and investment for resilient infrastructure Enhances preparedness and recovery from climate-induced disruptions
Global Infrastructure Risk & Resilience Model and Index (GIRI)	Power, highways, railways, transportation, water and wastewater, communications, oil and gas, education, health, housing	Earthquakes, tsunamis, landslides, floods, tropical cyclones, droughts	National	<ul style="list-style-type: none"> GIRI is grounded in a multi-hazard probabilistic risk assessment and adopts a global, holistic approach. This index ranks countries based on their expected Average Annual Loss (AAL) relative to critical economic, financial, environmental and social development variables. This probabilistic model enables governments to assess disaster risk in the context of fiscal sustainability. 	<ul style="list-style-type: none"> Assists in developing national resilience policies, strategies and standards by identifying contingent liabilities in the infrastructure sector Provides a comprehensive risk and resilience profile by country, enabling governments to make informed decisions and enhance infrastructure resilience
Physical Climate Risk Assessment Methodology (PCRAM)	Transportation, Energy, Water, Buildings, Telecommunications	Climate hazards, including extreme temperatures, flooding, storms and hurricanes, droughts and sea level rise	Project, National/Regional	<ul style="list-style-type: none"> PCRAM evaluates the operational, commercial and financial impacts of climate risks on assets. This methodology supports strategic investment reviews and enhances appraisal practices, contributing to more resilient and sustainable infrastructure. This methodology comprises four key steps: 1. Scoping and data gathering, 2. Materiality assessment 3. Resilience building 4. Economic and financial analysis 	<ul style="list-style-type: none"> Identifies and quantifies the benefits of investing in climate resilience measures, comparing them against the costs Ensures projects meet regulatory requirements for climate risk assessment and resilience planning

Frameworks	Relevant critical infrastructure (CI) coverage	Hazard coverage	Level	Key features	Use cases
Guidelines for climate-proofing investment in the transport sector	Transport (especially roads)	Natural hazards and extreme weather events	Project	<p>The guidelines outline a methodology with six activity sets and 20 steps, from rapid concept screening to defining implementation and monitoring frameworks. The six activities are as follows:</p> <ol style="list-style-type: none"> 1. Project screening and scoping 2. Impact assessment 3. Vulnerability assessment 4. Adaptation assessment 5. Implementation arrangements 6. Monitoring and evaluation 	<ul style="list-style-type: none"> ■ Assesses economic trade-offs of implementing climate adaptation measures ■ Guides investors in selecting resilient transport projects





Annexure 3

List of policies, action plans and programmes reviewed for different countries

Table 11: Global Policies and Programmes for Infrastructure Resilience and Adaptation

Country	Policies, action plans and programs
UK	National Adaptation Programme (NAP) 2023 – 2028 Government Vision and Action Plan for a Climate-Resilient Infrastructure, 2011 Sector Security and Resilience Plans, 2018
Australia	National Adaptation Framework, 2007 15-year Australian Infrastructure Plan, 2016 2023 Critical Infrastructure Resilience Strategy North Australia Infrastructure Facility (NAIF) (2023 – 2024) National Disaster Risk Reduction Framework, 2018
Japan	Fundamental Plan for National Resilience, 2014 2nd Basic Plan on Transport Policy (2021 – 2025) Act for Establishing Energy Supply Resilience, 2020 Resilient Infrastructure Public-Private Partnerships (PPPs): Contracts and Procurement, Japan, 2017
USA	Presidential Policy Directive (PPD) 21, 2013 National Infrastructure Protection Plan (NIPP), 2013 Building Resilient Infrastructure and Communities (BRIC) Programme, 2020 Energy Sector-Specific Plan, 2015 Transport Systems Sector-Specific Plan, 2015 Open Data Policy (M-13-13), 2013
India	Disaster Management Act, 2005 National Policy on Disaster Management, 2009 National Disaster Management Plan, 2019 National Action Plan on Climate Change (NAPCC), 2008 National Infrastructure Pipeline (NIP) (2020 – 2025) Draft National Energy Policy, 2017 Central Electricity Authority Regulations, 2023 National Geospatial Policy, 2022 National Electricity Policy, 2005 Innovation Policy for Indian Railways, 2022 National Urban Transport Policy, 2014 Updated First Nationally Determined Contribution Under Paris Agreement (2021-2030) Disaster Management Plan for Power Sector, 2021 Disaster Management in Indian Railways, 2014 India 2020 – Energy Policy Review Atal Mission for Rejuvenation and Urban Transformation (AMRUT), 2015 Pradhan Mantri Gram Sadak Yojana, 2000

Annexure 4

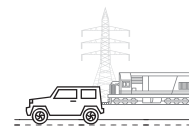
Best practices from international policies and action plans to mainstream disaster resilience within the infrastructure sector

To mainstream disaster resilience considerations within the infrastructure sector, various best practices from policies and action plans across countries were identified and

analyzed. These practices can be adopted to enhance the robustness, adaptability and sustainability of infrastructure systems in the face of natural hazards.

Table 12: Overview of International Policies and Action Plans for Infrastructure Resilience

International policies and action plan	Incorporated resilience measures
United Kingdom	
<p>Sectoral Plan for Resilience under National Adaptation Programme (NAP) (2023-2028)</p>	<p>In the UK, under the Climate Change Act (2008), the third National Adaptation Programme (NAP) 2023 – 2028 outlined Climate Change Adaptation (CCA) measures for various sectors. It emphasized the Sectoral Plan for resilience, where action points for each industry were shared, such as:</p> <p>Energy sector: Designate parties to assume maintenance responsibilities for codes and standards, with a clear mandate to enhance climate resilience, ensure business compliance and drive investment through government regulators.</p> <p>Transport (Railway) sector: Upgrade physical infrastructure by investing in earthworks and drainage systems and implement recommendations from the Rail Accident Investigation Branch report and Extreme Heat Taskforce reports.</p> <p>Transport (Road) sector: Prioritize maintenance and renewal activities in flood-prone areas and improve the drainage network, monitor pavement condition and identify adaptation measures.</p> <p><i>Source: Third National Adaptation Programme, Department for Environment, Food & Rural Affairs, 2023</i></p>
United States	
<p>Open Data Policy (M-13-13) 2013, emphasizing effective data management</p>	<p>The Open Data Policy (M-13-13) 2013 in the USA focuses on making information resources discoverable, accessible and usable for everyone to enhance opportunities and innovation. It formulates a framework for institutionalizing principles of effective information management at each stage of the information life cycle. The framework also helps decide whether certain information needs limited access for security reasons. Under the policy, different sectors must make a model plan to manage data, including the infrastructure sector.</p> <p><i>Source: Open Data Policy (M-13-13), 2013, United States Government</i></p>
United States	
<p>Presidential Policy Directive (PPD) 21 (2013) updating stakeholder roles and responsibilities</p>	<p>The Presidential Policy Directive (PPD) 21, 2013, under the Cybersecurity and Infrastructure Security Agency (CISA) of the USA stresses shared responsibility among federal, state, local and tribal entities, as well as public and private owners and operators of critical infrastructure. It refines and clarifies roles, responsibilities and critical infrastructure-related functions across the federal government, enhancing overall coordination and collaboration.</p> <p>“It is the policy of the United States to strengthen the security and resilience of its critical infrastructure against both physical and cyber threats. The Federal Government shall work with critical infrastructure owners and operators and SLTT entities to take proactive steps to manage risk and strengthen the security and resilience of the Nation’s critical infrastructure, considering all hazards that could have a debilitating impact on national security, economic stability, public health and safety, or any combination thereof.”</p> <p><i>Source: Presidential Policy Directive/PPD-21, Critical Infrastructure Security and Resilience, 2013</i></p>



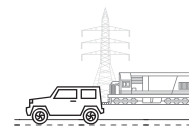
International policies and action plan	Incorporated resilience measures
Japan	
<p>Risk allocation in policy and legal frameworks for PPPs and disaster management</p>	<p>In the PPP projects in Japan, the 'division of responsibilities against force majeure among public and private entities', as defined in Article 29, Paragraph 4, of the Standard Conditions of Contracts for Public Works, is referred to when responding to disasters defined as force majeure. PPP projects often utilize a '1 per cent rule' from the Standard Conditions of Contracts for Public Works, which dictates that the private contractor or operator is responsible for damages up to 1 per cent of the contract value or initial investment cost in the event of force majeure. At the same time, the public sector bears any costs exceeding that threshold. This framework helps delineate clear responsibilities and risk-sharing in the event of unforeseen circumstances. However, in concession model projects, which involve selling operational rights of public facilities to private entities, this standard rule is not routinely applied. Instead, risk allocation, particularly in the context of disasters, is negotiated on a case-by-case basis. This is because greater risks are inherently transferred to the private sector within concession models, requiring tailored agreements that reflect the specific nature and requirements of each project.</p> <p><i>Source: Resilience Infrastructure Public-Private Partnership (PPPs): Contracts and Procurement, Japan, World Bank, 2017</i></p>
<p>Fundamental Plan for National Resilience 2018, incorporating procedures for vulnerability assessment</p>	<p>The Fundamental Plan for National Resilience 2018 in Japan aims to promote resilience in Japan by preventing loss of life, maintaining state and societal functions, minimizing property damage and facilitating swift recovery. To refine and update adaptation and resilience measures and promote resilience in different sectors, the plan includes procedures for vulnerability assessments. It includes anticipating the risks posed by large-scale disasters, analyzing possible processes in which disruptive events can occur, assessing the disaster vulnerability of each sector and conducting cross-sectoral analysis of disaster mitigation measures.</p> <p><i>Source: Fundamental Plan for National Resilience: For Building a Strong and Flexible Country, 2018</i></p>
Australia	
<p>North Australia Infrastructure Facility (NAIF) 2023-2024, incentivizing private sector investment for critical infrastructure</p>	<p>The Australian government's flagship financing agency, the North Australia Infrastructure Facility (NAIF), allocated \$7 billion for infrastructure project development, which included building resilience in sectors such as energy, transport, agriculture, social infrastructure, logistics and water. It incentivized private sector investment in infrastructure development primarily by providing concessional financing, comprising flexible terms, lower interest rates and more extended repayment periods through state and territorial governments. As a result, for four investment decisions in 2023-2024, NAIF loans financed approximately 17 percent of the project's total capital value and the private sector contributed 83 percent of the value.</p> <p><i>Source: North Australia Infrastructure Facility (NAIF), Annual Report, 2023-2024</i></p>
<p>National Disaster Risk Reduction Framework (2018) emphasizes DRR awareness and capacity building</p>	<p>The National Disaster Risk Reduction Framework (2018) of Australia prioritizes DRR awareness and capacity building by emphasizing the need to enhance understanding and skills at all levels of society, including individuals, communities, businesses and government entities. This priority area focuses on improving education and training programmes to equip stakeholders with the knowledge necessary to prepare for and respond to disasters effectively. It encourages collaboration across sectors to share best practices and resources, aiming to foster a culture of resilience and proactive risk management throughout the country.</p> <p><i>Source: National Disaster Risk Reduction Framework, 2018</i></p>

Annexure 5

Guidelines, Codes & Standards for building resilient infrastructure design

List of codes/guidelines for the safety of structures from natural hazards from the Indian Road Congress (IRC)

- 1 IRC:SP-73-2018 Manual of Specifications & Standards for Two-Laning of Highways with Paved Shoulder (Second Revision)
- 2 IRC:SP-84-2019 Manual of Specifications and Standards for Four-Laning of Highways (Second Revision)
- 3 IRC:SP-87-2019 Manual of Specifications & Standards for Six Lanning of Highways (Second Revision)
- 4 IRC:SP-91-2019 Guidelines for Road Tunnels (First Revision)
- 5 IRC:SP-99-2013 Manual of Specifications and Standards for Expressways
- 6 IRC:5- 2015 Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design (Eighth Revision)
- 7 IRC:6-2017 Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Load Combinations (Seventh Revision)
- 8 IRC:36-2010 Recommended Practice for Construction of Earth Embankments and Sub-Grade for Road Works (First Revision)
- 9 IRC:112- 2020 Code of Practice for Concrete Road Bridges (First Revision)
- 10 IRC:22-2015 Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit States Design) (Third Revision)
- 11 IRC:24- 2010 Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method) (Third Revision)
- 12 IRC:34-2011 Recommendations for Road Construction in Areas Affected by Water Logging, Flooding and/or Salt Infestation (First Revision)
- 13 IRC:40-2002 Standard Specifications and Code of Practice for Road Bridges, Section IV – (Brick, Stone and Cement Concrete Block Masonry) (Second Revision)
- 14 IRC:45-1972 Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well Foundations of Bridges
- 15 IRC:52- 2019 Guidelines for the Alignment Survey and Geometric Design of Hill Roads (Third Revision)
- 16 IRC:56- 2011 Recommended Practices for Treatment of Embankment and Roadside Slopes for Erosion Control (First Revision)
- 17 IRC:56-2011 Recommended Practices for Treatment of Embankment and Roadside Slopes for Erosion Control (First Revision)
- 18 IRC:75- 2015 Guidelines for the Design of High Embankments (First Revision)
- 19 IRC:78-2014 Standard Specifications and Code of Practice for Road Bridges, Section VII- Foundations and Substructure (Revised Edition)
- 20 IRC:83-2015 (Part-I) Standard Specifications and Code of Practice for Road Bridges, Section IX Bearings, Part I: Roller & Rocker Bearings (Second Revision)
- 21 IRC:83-2018 (Part II) Standard Specifications and Code of Practice for Road Bridges, Section: IX – Bearings (Elastomeric Bearings), Part II (Second Revision)



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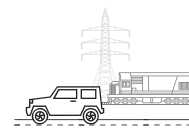
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- 25 IRC:104- 1988 Guidelines for Environmental Impact Assessment of Highway Projects
- 26 IRC:112- 2020 Code of Practice for Concrete Road Bridges (First Revision)
- 27 IRC:SP:13-2004 Guidelines for the Design of Small Bridges and Culverts (First Revision)
- 28 IRC:SP:20-2002 Rural Roads Manual
- 29 IRC:SP:35-1990 Guidelines for Inspection and Maintenance of Bridges
- 30 IRC:SP:42-2014 Guidelines on Road Drainage (First Revision)
- 31 IRC: SP:48- 1998 Hill Road Manual
- 32 IRC:SP:50- 2013 Guidelines on Urban Drainage (First Revision)
- 33 IRC:SP:54-2018 Project Preparation Manual for Bridges (First Revision)
- 34 IRC:SP:65-2018 Guidelines for Design and Construction of Segmental Bridges (First Revision)
- 35 IRC:SP:66-2016 Guidelines for Design of Continuous Bridges (First Revision)
- 36 IRC:SP:82-2008 Guidelines for Design of Causeways and Submersible Bridges
- 37 IRC:SP-91-2019 Guidelines for Road Tunnels (First Revision)
- 38 IRC:SP-93-2017 Guidelines on Requirements for Environmental Clearances for Road Projects
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- 41 IRC:SP-106-2015 Engineering Guidelines on Landslide Mitigation Measures for Indian Roads
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- 43 IRC:SP:112-2017 Manual for Quality Control in Road and Bridge Works
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- 49 MORT&H Pocketbook for Bridge Engineers, 2000 (First Revision)
- 50 MORT&H Pocketbook for Highway Engineers, 2019 (Third Revision)
- 51 MORT&H Specifications for Road and Bridge Works, 2013 (Fifth Revision)
- 52 MORT&H Guidelines for Expressways Part I and Part II

List of codes/guidelines for the safety of structures from natural hazards for the Railway from the Research Design & Standards Organisation (RDSO)

- 1 RBF-20: "Estimation of design discharge based on regional flood frequency approach for sub-zones 3(a), 3 (b), 3 (c) & 3 (e)"
- 2 RBF-22: "50-year 24-hour set of isopluvial maps of India maps of short duration ratios"
- 3 RBF-23: "Validation of flood estimation report No. UNT-7-1983 for sub-zone-3 (f)"
- 4 RBF-24: "Validation of flood estimation report No. 3/1980 for sub-zone-3 (f)"
- 5 RBF-25: "Estimation of design discharge based on regional flood frequency approach for sub-zone-3 (f)"
- 6 RBF-26: "Validation of flood estimation report No. UGP -9-1984 for sub-zone-1 (e)"
- 7 RBF-27: "Validation of design discharge based on regional flood frequency approach for sub-zone-3 (e)"
- 8 RBF-28: "Estimation of design discharge based on regional flood frequency approach for sub-zone-3 (i)"
- 9 RBF-29: "Estimation of design discharge based on regional flood frequency approach of sub-zone-3 (b)"
- 10 RBF-32: "Validation of flood estimation report no c/16/1988 Subzone-1 (b) (Chambal basin)"
- 11 RBF-33: "Estimation of design discharge based on regional flood frequency approach for sub-zone-1 (d) (Sone basin)"
- 12 RBF-34: "Validation of flood estimation report no. S/15/1987 sub-zone-1 (d) (Sone basin)"
- 13 GE-1: "Guidelines- Erosion control on slopes of banks and cuttings"
- 14 GE-6: "Guidelines for earthwork in conversion projects"

List of codes/guidelines for the safety of structures from natural hazards for the Power sector from the Central Electricity Authority (CEA)

- 1 Report of the task force on cyclone resilient, robust electricity transmission and distribution (T&D) infrastructure in coastal areas (2021)
- 2 Technical Standards for Construction of Electrical Plant Lines (2022)
- 3 Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations (2022)
- 4 Manual on Transmission Planning Criteria (2023)
- 5 Central Electricity Authority (Grid Standards) Regulations (2010)
- 6 Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations (2007, updated 2013, updated 2019)



List of codes/guidelines for the safety of structures from natural hazards from the Bureau of Indian Standards (BIS)

I General Structural Safety

- 1 IS:456:2000 "Code of Practice for Plain and Reinforced Concrete"
- 2 IS:800-1984 "Code of Practice for General Construction in Steel"

II Protection from Cyclones/Windstorms

- 3 IS:875 (3)-1987 "Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures, Part 3, Wind Loads"
- 4 IS:2911- 1973 "Guideline for construction of cyclone shelters".

III Earthquake Protection

- 5 IS:1893-2014 "Criteria for Earthquake Resistant Design of Structures Part 3 (Fifth Revision): Bridges and Retaining Walls"
- 6 IS:13920-1993 "Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces – Code of Practice"

IV Flood Management

- 7 IS:11532 – 1995 "Construction and maintenance of river embankments (levees)- Guidelines"
- 8 IS:12094 – 2000 "Guidelines for Planning and Design of River Embankments (Levees)"
- 9 IS:14262 – 1995 "Planning and design of revetments- Guidelines"

v Landslide Hazard

- 10 IS:14458 (Part 1): 1998 Guidelines for retaining wall for hill area: Part 1 Selection of type of wall
- 11 IS:14458 (Part 2): 1997 Guidelines for retaining wall for hill area: Part 2 Design of retaining/ breast walls
- 12 IS:14458 (Part 3): 1998 Guidelines for retaining wall for hill area: Part 3 Construction of dry-stone walls
- 13 IS:14680: 1999 Guidelines for landslide control
- 14 IS:14948: Code of practice for Reinforcement of Rock Slopes with plain edge of failure

Annexure 6

Good practices on project monitoring

Good practices for infrastructure construction and operations monitoring utilizing advanced technologies

Crossrail Project – United Kingdom

The Crossrail Project in the United Kingdom employed Building Information Model (BIM) to create detailed digital models of the railway infrastructure, aiding in construction management and coordination. The Internet of Things sensors were used to monitor environmental conditions and structural health during and after construction.

Advanced earthquake early warning system for Shinkansen (bullet trains), East Japan Railway Company (JR East) – Japan

JR East uses the Urgent Earthquake Detection and Alarm System (UrEDAS) to receive early warnings of seismic activity. The system can automatically slow down or stop trains to prevent derailments and ensure passenger safety. This involves the integration of real-time seismic data with railway operations.

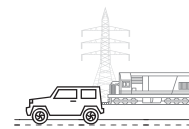
Utilizing real-time hydrological data and predictive models, Flood Early Warning System for Roads – Thailand

The Bangkok Metropolitan Administration (BMA) installed sensors in key flood-prone areas to monitor water levels and rainfall. The system provides early warnings to road operators, enabling them to close roads and divert traffic to prevent accidents and congestion, using real-time hydrological data and predictive models.

Smart Grid and EWS Integration – Italy

ENEL's smart grid system uses advanced sensors and communication networks to monitor grid conditions. Weather data integration allows the grid to anticipate and respond to extreme weather events, reducing downtime and improving resilience.

Source: Cross-rail project, JR East, Mott MacDonald, Enel



Annexure 7

Detailed findings from the RCBA tool in the individual projects

The outputs of the RCBA tool for the five projects are as follows:

Project 1: Rudraprayag to Joshimath Package-III

Output	Project 1
Indicators	Details
Asset Type	National Highway
Name of project	Rudraprayag to Joshimath Package-III
Project Cost (As-Is) (Rs Lakh)	38,665
State	Uttarakhand
Hazard type	Landslide
Resilience measure selected	Landslide zone treatment, Breast wall, Retaining wall, Slope protection
Cost of selected resilience measure (Rs, Lakh)	3,135
Absolute savings (Rs, Lakh)	22,684
Net present value (Rs, Lakh)	228
Internal rate of return (%)	14.81%
Break-even point (Operational years)	8
Benefit-cost ratio (BCR)	7

Absolute Savings (Benefit) = sum of {(Operational & Maintenance Expenditure + Reconstruction & Recovery costs) in (As-is) - (Resilience Scenario)} for all time periods

IRR: Internal Rate of Return for benefits generated as a result of Resilience Costs (delta) incurred initially.

NPV: Net Present Value of initial Resilience Cost (Delta) & Benefit (Savings) across the lifecycle.

Break Even Point: The year of operation wherein the cumulative Resilience Benefit = Resilience cost initially incurred.

Benefit Cost Ratio: Absolute Savings / (Delta) Project Cost



There is a benefit of Rs 7 for every rupee invested in resilience. The benefits mentioned includes only the Recovery & Reconstruction costs avoided, this number is likely to be much higher if we factor for Revenue losses avoided & other economic benefits resulting from the resilience measures.

Project 2: 4-L Silchar-Assam-Jiribam-Pkg-1

Output	Project 2
Indicators	Details
Asset type	National Highway
Name of project:	4-L Silchar-Assam-Jiribam-Pkg-1
Project Cost (As-Is) (Rs. Lakh)	61,749
State	Assam
Hazard type	Flood
Resilience measure selected	Drainage & Protection, Slope protection, Breast wall, Retaining wall
Cost of selected resilience measure (Rs, Lakh)	2,787
Absolute savings (Rs, Lakh)	21,819
Net present value (Rs, Lakh)	251
Internal rate of return (%)	14.97%
Break-even point (Operational years)	8
Benefit Cost Ratio (BCR)	8

Absolute Savings (Benefit) = sum of {(Operational & Maintenance Expenditure + Reconstruction & Recovery costs) in (As-is) - (Resilience Scenario)} for all time periods

Break Even Point: The year of operation wherein the cumulative Resilience Benefit = Resilience cost initially incurred.

IRR: Internal Rate of Return for benefits generated as a result of Resilience Costs (delta) incurred initially.

Benefit Cost Ratio: Absolute Savings / (Delta) Projec Cost

NPV: Net Present Value of initial Resilience Cost (Delta) & Benefit (Savings) across the lifecycle.



There is a benefit of Rs 8 for every rupee invested in resilience. The benefits mentioned includes only the Recovery & Reconstruction costs avoided, this number is likely to be much higher if we factor for Revenue losses avoided & other economic benefits resulting from the resilience measures.

Project 3: Indore-Budni New Railway Line

Output	Project 3
Indicators	Details
Asset type	Railway track – Broad Gauge
Name of project	Indore-Budni New Railway Line
Project Cost (As-Is) (Rs. Lakh)	747,400
State	Madhya Pradesh
Hazard type	Flood
Resilience measure selected	Embankment
Cost of selected resilience measure (Rs, Lakh)	12,181
Absolute savings (Rs, Lakh)	23,274
Net present value (Rs, Lakh)	(8,292)
Internal rate of return (%)	4.78%
Break-even point (operational years)	11
Benefit-cost ratio (BCR)	2

Absolute Savings (Benefit) = sum of {(Operational & Maintenance Expenditure + Reconstruction & Recovery costs) in (As-is) - (Resilience Scenario)} for all time periods

IRR: Internal Rate of Return for benefits generated as a result of Resilience Costs (delta) incurred initially.

NPV: Net Present Value of initial Resilience Cost (Delta) & Benefit (Savings) across the lifecycle.

Break Even Point: The year of operation wherein the cumulative Resilience Benefit = Resilience cost initially incurred.

Benefit Cost Ratio: Absolute Savings / (Delta) Project Cost



There is a benefit of Rs 2 for every rupee invested in resilience, However the NPV comes negative. The benefits mentioned includes only the Recovery & Reconstruction costs avoided, this number is likely to be much higher if we factor for Revenue losses avoided & other economic benefits resulting from the resilience measures.

Project 4: Transmission System for Mundra Ultra Mega Power Project

Output	Project 4
Indicators	Details
Asset type	Transmission
Name of project	Transmission System for Mundra Ultra Mega Power Project
Project Cost (As-Is) (Rs, Lakh)	454,575
State	Gujarat
Hazard type	Cyclone
Resilience measure selected	Underground cables in vulnerable stretches
Cost of selected resilience measure (Rs, Lakh)	57,268
Absolute savings (Rs, Lakh)	658,901
Net present value (Rs, Lakh)	27,871
Internal rate of return (%)	18.51%
Break-even point (operational years)	3
Benefit-cost ratio (BCR)	12

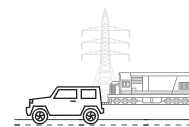
Absolute Savings (Benefit) = sum of {(Operational & Maintenance Expenditure + Reconstruction & Recovery costs) in (As-is) - (Resilience Scenario)} for all time periods

IRR: Internal Rate of Return for benefits generated as a result of Resilience Costs (delta) incurred initially.

NPV: Net Present Value of initial Resilience Cost (Delta) & Benefit (Savings) across the lifecycle.

Break Even Point: The year of operation wherein the cumulative Resilience Benefit = Resilience cost initially incurred.

Benefit Cost Ratio: Absolute Savings / (Delta) Project Cost



There is a benefit of Rs 12 for every rupee invested in resilience. The benefits mentioned includes only the Recovery & Reconstruction costs avoided, this number is likely to be much higher if we factor for Revenue losses avoided & other economic benefits resulting from the resilience measures.

Project 5: Strengthening of Srinagar-Leh Transmission System

Output	Project 5
Indicators	Details
Indicators	Transmission
Name of project	Strengthening of Srinagar-Leh Transmission System
Project Cost (As-Is) (Rs, Lakh)	103,305
State	Ladakh and Jammu and Kashmir
Hazard type	Flash floods
Resilience measure selected	High tension low sag conductors, Underground transmission corridor
Cost of selected resilience measure (Rs, Lakh)	8,264
Absolute savings (Rs, Lakh)	54,569
Net present value (Rs, Lakh)	7,216
Internal rate of return (%)	22.29%
Break-even point (operational years)	3
Benefit-cost ratio (BCR)	7

Absolute Savings (Benefit) = sum of {(Operational & Maintenance Expenditure + Reconstruction & Recovery costs) in (As-is) - (Resilience Scenario)} for all time periods

IRR: Internal Rate of Return for benefits generated as a result of Resilience Costs (delta) incurred initially.

NPV: Net Present Value of initial Resilience Cost (Delta) & Benefit (Savings) across the lifecycle.

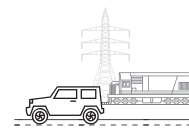
Break Even Point: The year of operation wherein the cumulative Resilience Benefit = Resilience cost initially incurred.

Benefit Cost Ratio: Absolute Savings / (Delta) Project Cost



There is a benefit of Rs 7 for every rupee invested in resilience. The benefits mentioned includes only the Recovery & Reconstruction costs avoided, this number is likely to be much higher if we factor for Revenue losses avoided & other economic benefits resulting from the resilience measures.





Annexure 8

Resilient Projects Appraisal Checklist

Aligned with investor-centric Approach

Risk	
Questions	Remarks
<p>High-level Disaster & Climate Risk screening:</p> <p>Does the project fall in the priority category based on the Disaster Risk Priority Matrix?</p>	
<p>Detailed Risk Assessment:</p> <p>Whether the Detailed Project Report consists of findings from 'Hazard Risk & Vulnerability Assessment'?</p>	
<p>Risk Mitigation/Resilience Measures:</p> <p>What are the resilience measures taken to mitigate the Disaster & Climate risks?</p>	
Return	
Questions	Remarks
<p>Financial Returns*:</p> <p>What are the expected financial returns for Resilience measures adopted across the project Lifecycle? (Use the RCBA tool to assess it)</p>	
<p>Economic Returns**(Optional):</p> <p>What are the Economic returns of the resilience measures adopted across the project Lifecycle?</p>	
Value	
Questions	Remarks
<p>Adaptation Co-Benefits:</p> <p>What are the Co-benefits of the Resilience measures adopted? (Social Impact, Climate change Mitigation, Biodiversity conservation)</p>	

*Financial return includes Avoided Reconstruction & Repair costs & Avoided Revenue losses due to disruption

**Highlight the Economic costs avoided such as loss to the Primary, secondary & tertiary sectors (Local, Regional or National level) due to infrastructure damage

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