CDRI
Coalition for Disaster Resilient Infrastructure

Mainstreaming Disaster Resilience into Infrastructure Projects

Insights from Infrastructure Sectors in India

Executive Summary

1 Introduction

With the frequency and intensity of natural hazards increasing, the average annual loss (AAL) for global infrastructure is estimated to be between $732 billion and $845 billion.[1] This is roughly 14 percent of the 2021-2022 global gross domestic product (GDP) growth.[2] Globally, over the last 50 years, the number of disasters–including extreme weather events–have increased fivefold.[4] As the frequency of such events rises, so too do the associated vulnerabilities and risks. Data from 1980 to 2013 shows a clear upward trend in the number of annual disaster events (Figure 1).[5]

In India, the increasing frequency and severity of disasters pose a significant threat to critical infrastructure investments, which are crucial systems responsible for promoting the national economy, public health, public safety and national security. Disruption of such vital infrastructure can significantly impact the country's socio-economic functions as disasters in India account for up to 2 percent of its GDP and can reduce central government revenue by up to 12 percent annually.[3]

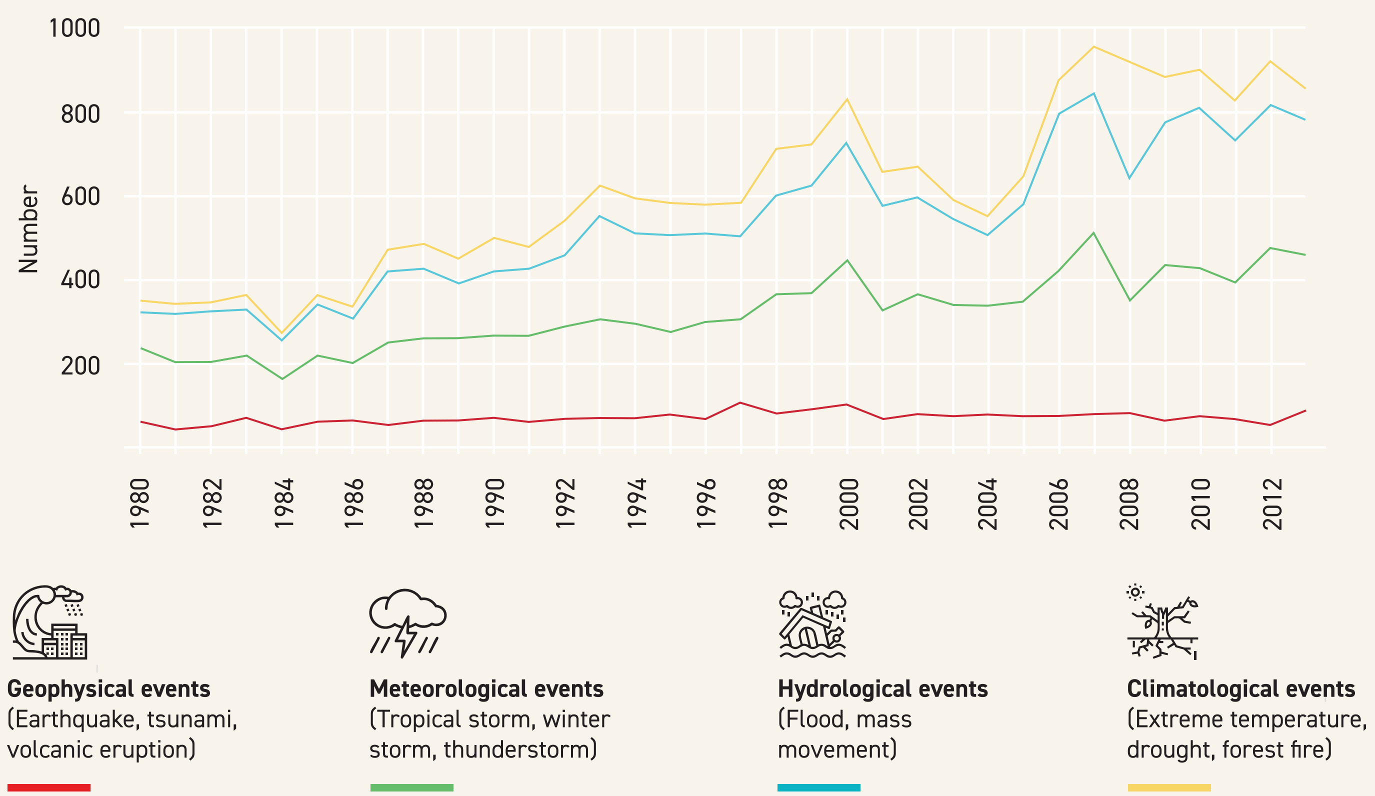


Figure 1. Annual number of disasters associated with natural events around the world from 1980-2013 (Source: NatCatSERVICE, Munich Re, 2014)

To address existing disaster risks while advancing infrastructure development goals, the Coalition for Disaster Resilient Infrastructure (CDRI) — as an international organization — is committed to supporting governments in integrating disaster resilience into its infrastructure projects.

This study titled 'Mainstreaming Disaster Resilience into Infrastructure Projects' has been undertaken with support and guidance from the Department of Economic Affairs, Ministry of Finance in India. As part of this study, the Resilience Cost-Benefit Analysis (RCBA) tool and the Toolkit for Disaster Resilience have been developed to support the government and line ministries in addressing disaster risks.

[1]All dollar ($) figures refer to US dollars unless otherwise specified.
[2]Global Infrastructure Resilience Report, CDRI, (2023)
[3]Handbook on Disaster Management for Nodal Officers, NIDM, (2019)
[4]World Meteorological Organization (2021)
[5]NatCatSERVICE, Munich Re, (2014)

1.1 Scope of the Study

The study focuses on identifying ways to mainstream disaster resilience in three selected infrastructure sectors: roads, railways and power. It identifies gaps in resilience in key areas, including policy and institutions, infrastructure development process, infrastructure development projects and financing. Action points are suggested to address the gaps in disaster resilience. To address these gaps, the study developed a Resilience Cost-Benefit Analysis (RCBA) tool, which analyzes the benefits of investing in resilience. Additionally, it provides a toolkit designed to incorporate disaster resilience considerations into infrastructure projects.

The RCBA tool comprises an interactive spreadsheet-based application and a user guide. It utilizes project-level data as inputs and comprises a hazard catalogue that includes publicly available data from sources such as the India Meteorological Department (IMD), the Building Materials and Technology Promotion Council (BMTPC) and UNDRR's Global Assessment Reports (GAR). The tool helps stakeholders make informed decisions about investing in resilience measures during the initial phases of a project.

The toolkit for disaster resilience comprises four components: a) a list of resilience measures for bidding and contractual documents, b) a list of design options for asset resilience, c) a guidance document for line ministries on incorporating disaster resilience aspects during the project identification and appraisal phases and d) a guidance document for potential bidders to help them prepare project proposals that include disaster resilience considerations.

Collectively, these resources are intended to support line ministries in integrating disaster resilience into the project identification and appraisal stages, while also enabling private sector bidders to effectively plan for and budget disaster resilience measures in their project proposals.

Tasks undertaken to identify gaps in resilience

Literature review of global challenges faced by critical infrastructure due to natural hazards, global best practices incorporating resilience measures and existing resilience frameworks

Stakeholder consultations with line ministries, implementing agencies like Power Grid Corporation of India Limited (PGCIL), technical bodies like Indian Road Congress (IRC), National Disaster Management Authority (NDMA), national financial institutions and MDBs/DFIs

Appraisal of standard agreements such as Revised Standard EPC Agreement for NH and Centrally-sponsored road works proposed to be implemented on EPC Mode, Standard EPC Tender Document for Single Stage Two Packet System and Standard Bidding Documents for procurement of Inter-State Transmission System (ISTS) through Tariff Based Competitive Bidding (TBCB) process

Mainstreaming disaster resilience in critical infrastructure

Resilience Cost Benefit Analysis (RCBA) tool

- Interactive tool
- User guide

Toolkit for disaster resilience

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

List 2: List of design options for asset resilience

Guidance Document 1: Project identification and appraisal guidance document for line ministries

Guidance Document 2: Project proposal preparation guidance document for potential bidders

Recommendations for incorporating resilience across key areas

- Policy and institution
- Infrastructure development process
- Infrastructure development projects
- Financing

Outputs of the study

Figure 2. Methodology and outputs of the study

Resilience frameworks, indices and methodologies drafted by organizations such as the World Bank, Asian Development Bank and ARUP have been developed in the context of infrastructure resilience. These assessed infrastructure resilience frameworks demonstrate broad applicability across various phases of the project life cycle, offering robust methodologies and measures to enhance infrastructure resilience.

Frameworks reviewed under the study

- 2011 — Guidelines for Climate Proofing Investment in the Transport Sector: Road Infrastructure Projects, Asian Development Bank
- 2013 — Resilience Measurement Index
- 2015 — Measuring Critical Infrastructure Resilience, ETH Zurich
- 2016 — Critical Infrastructure Resilience Index (CIRI)
- 2018 — EU-Circle Resilience Framework, National Centre for Scientific Research "Demokritos"
- 2021 — Resilience Rating System (RSS), World Bank Group
- 2021 — Physical Climate Risk Assessment Methodology (PC RAM), Coalition for Climate Resilient Investment (CCRI)
- 2022 — Energy Resilience Framework, ARUP
- 2022 — Infrastructure Resilience Planning Framework (IRFP), Cybersecurity and Infrastructure Security Agency (CISA) (2022)
- 2022 — Global Infrastructure Risk and Resilience Model and Index (GIRI), Coalition for Disaster Resilient Infrastructure (CDRI)

1.2 International Good Practices

Countries around the world, including Australia, China, Japan, Singapore, the United Kingdom and the United States, have taken significant measures to incorporate and enhance resilience measures for their infrastructure (including power, roads and railways), which helps mitigate disaster risks. Good practices and learnings from these countries are included in the two illustrations below and categorized under the following two heads:

Structural:

- Design and construction standards
- Retrofitting and upgrades
- Redundancy and back-up systems
- Innovative technologies

Non-structural:

- Policy and regulation
- Emergency planning and management
- Data and monitoring systems
- Community and stakeholder management

While developed countries have begun addressing financial liabilities in cases of natural disasters, several countries in the Asia Pacific region—facing a higher number of natural hazards—are increasingly incorporating resilience clauses into their public-private partnership (PPP) contracts and other procurement documents.

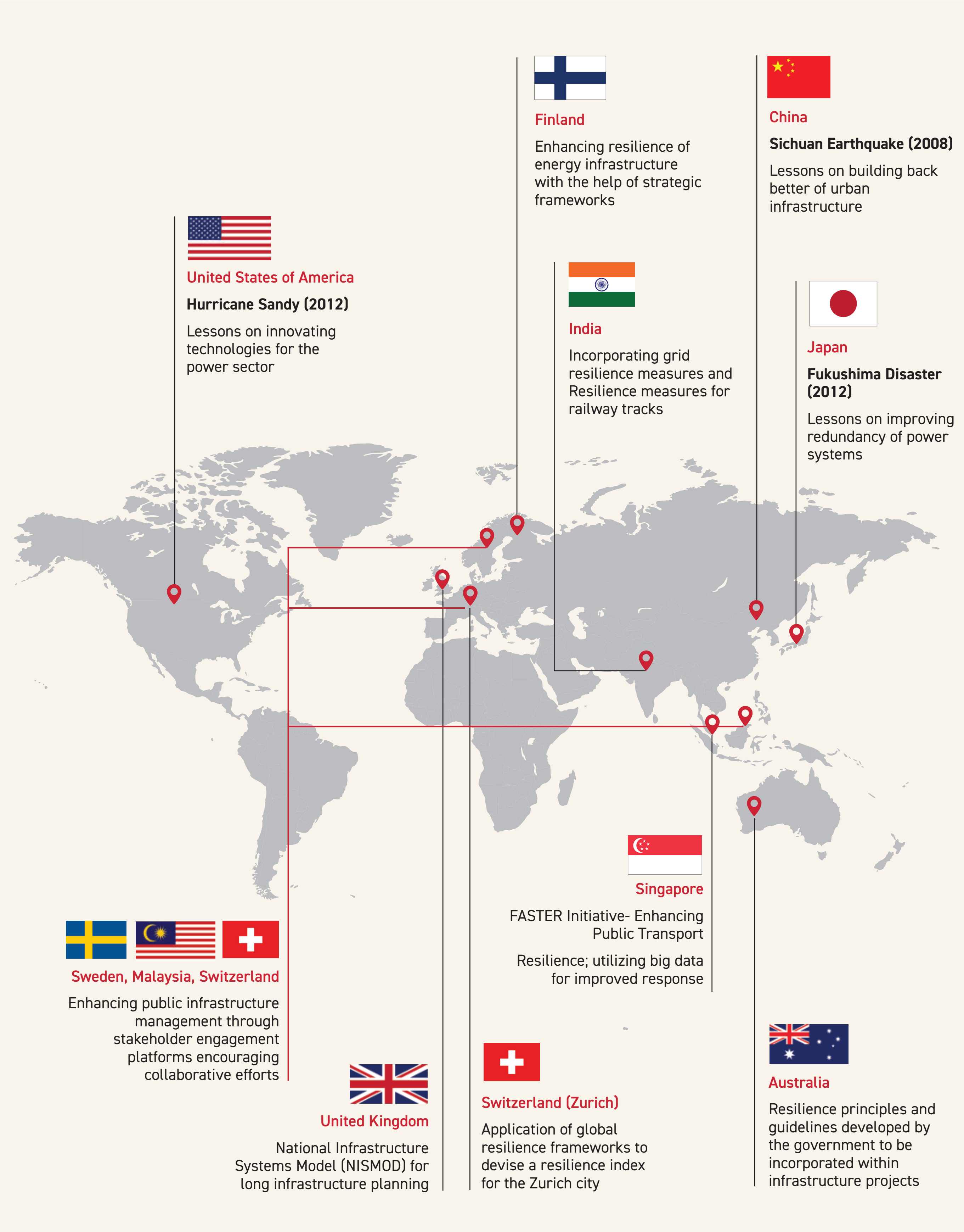


Figure 3: Some Global best practices: Structural and Non Structural Resilience measures

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, Melboure, earthquake, floods expected once every 100 years etc.[1]

Treats weather events separately from 'force majeure':

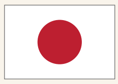
A key issue is whether climate change impacts are covered by relief, compensation, or force majeure clauses in PPP contracts.

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

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]



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]

Figure 4. Good practices for integrating resilience considerations in standard agreements and contractual documents (non-structural measures)

A literature review was conducted to assess global challenges to critical infrastructure from natural hazards. It also examined international good practices and existing resilience frameworks, capturing key insights on infrastructure resilience. In parallel, stage-wise stakeholder consultations were held to evaluate the current level of disaster resilience in infrastructure projects. An appraisal of standard agreements and contractual documents in the roads, railways and power sectors was also carried out. The aim was to identify gaps in mainstreaming resilience in India's infrastructure planning. Based on the literature review, stakeholder consultations and contract appraisal, gaps were identified across five key areas.

Five key gap areas

1 In standard contractual documents	2 Across the project lifecycle	3 In data and risk assessment systems	4 In capacity	5 In financing and risk coverage

The identified gaps include the absence of resilience measures in existing sectoral policies and standard contractual documents across the three identified infrastructure sectors.

Across the project lifecycle, there were gaps in the assessment of natural hazard risks during the infrastructure planning and design phase, the absence of additional resilience provisions that exceed the minimum design codes and a lack of effective enforcement of existing codes and standards.

Furthermore, the lack of a comprehensive disaster database and risk assessment framework led to issues with the collation and storage of hazard, exposure, and loss and damage data. Severe gaps in capacities and expertise amongst infrastructure stakeholders accompany this.

Lastly, there is a lack of dedicated resilience financing sources for infrastructure projects and limited insurance coverage for hazard risks across different project phases, which makes mainstreaming disaster resilience into infrastructure projects a challenge.

Key Actions for Stakeholders

1. Integrate resilience considerations within sectoral policies
2. Create institutional mechanisms for disaster risk data management and dissemination
3. Ensure equitable responsibility allocation and cross-sectoral collaboration
4. Create an enabling environment for the private sector to enhance resilience investments
5. Mandate regular monitoring and evaluation of the incorporated resilience measures
6. Mandate risk and vulnerability assessment during project initiation
7. Enhance technical expertise and capacity-building initiatives
8. Update design standards with the evolving hazard scenario
9. Establish thresholds for hazard parameters contextual to the site and project and include them in force majeure clauses
10. Include provisions to allocate and transfer risk among stakeholders
11. Appoint independent engineers to proof-check project design and safety consultants to check compliance with resilience measures
12. Extend the defect liability period
13. Make existing public-private partnerships (PPP) and engineering, procurement and construction (EPC) policies

Private Sector

1. Ensure incorporation of resilience measures in all project stages
2. Incorporate resilience considerations during the project proposal's development and submission
3. Incorporate resilience considerations during project

Institutional Development Partners and Financial Institutions

1. Develop capacity-building programmes, training modules and guidance documents, and toolkits to build knowledge on resilience investment, disaster risk reduction (DRR), and disaster risk financing and insurance (DRFI) and implement it
2. Make provisions to expand insurance coverage to all the project phases

Recommendations across the project lifecycle

Stage 1
Project Preparation: Feasibility/DPR stage

Step 1

Risk Assessment

DPR consultant checks for the Disaster Risk priority of a project?

Parameters

Hazard profile	Economic significance	Network redundancy

Is the project a priority based on the Disaster Risk priority matrix?

If No Exit

If Yes

Stage 2
Procurement

Step 6

Risk Transfer instruments

Government and private players could avail the option of **cover from insurance agencies** for their share of disaster risks.

In the wake of an underdeveloped private infrastructure insurance market, the **proposed risk pool and other risk instruments, such as CAT bonds**, could be used for risk transfer.

Stage 3
Implementation

Step 7

Resilience check by experts using a checklist for ensuring resilience incorporation.

Stage 4
Operation and Maintenance

Step 9

A decision support system (DSS) could also be introduced for asset tracking, data management, and providing weather alerts and warnings, ensuring real-time monitoring and resilience compliance.

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 and 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 Recommendations for mainstreaming disaster resilience in infrastructure

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 an equitable allocation of risk and responsibility to relevant stakeholders to determine liabilities in cases of hazard impacts. This distribution should be specified based on the hazard thresholds established by the Project Implementing Authorities based on HRVA results from the DPR stage 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 (DLP) under the Engineering, Procurement, and Construction (EPC) mode is very short, ranging up three 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 and Highways, Government of India (MoRTH) has recently extended the DLP for EPC projects up to 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.

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 greater resilience, infrastructure projects need to go beyond the minimum design standards laid out by the respective standard-setting bodies, so that they can 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, implementing protective measures, providing redundancies and increasing preparedness based on the specific data and experiences of local hazards.

- **Localized resilience measures:**

  Incorporating new construction technologies and innovative implementation mechanisms can enhance project outcomes. The use of local technology with stakeholders and community involvement may help achieve more resilience at the project and community levels (based on community experience). Integrating these local and indigenous measures into the design can help increase resilience in a financially viable manner.

- **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.**

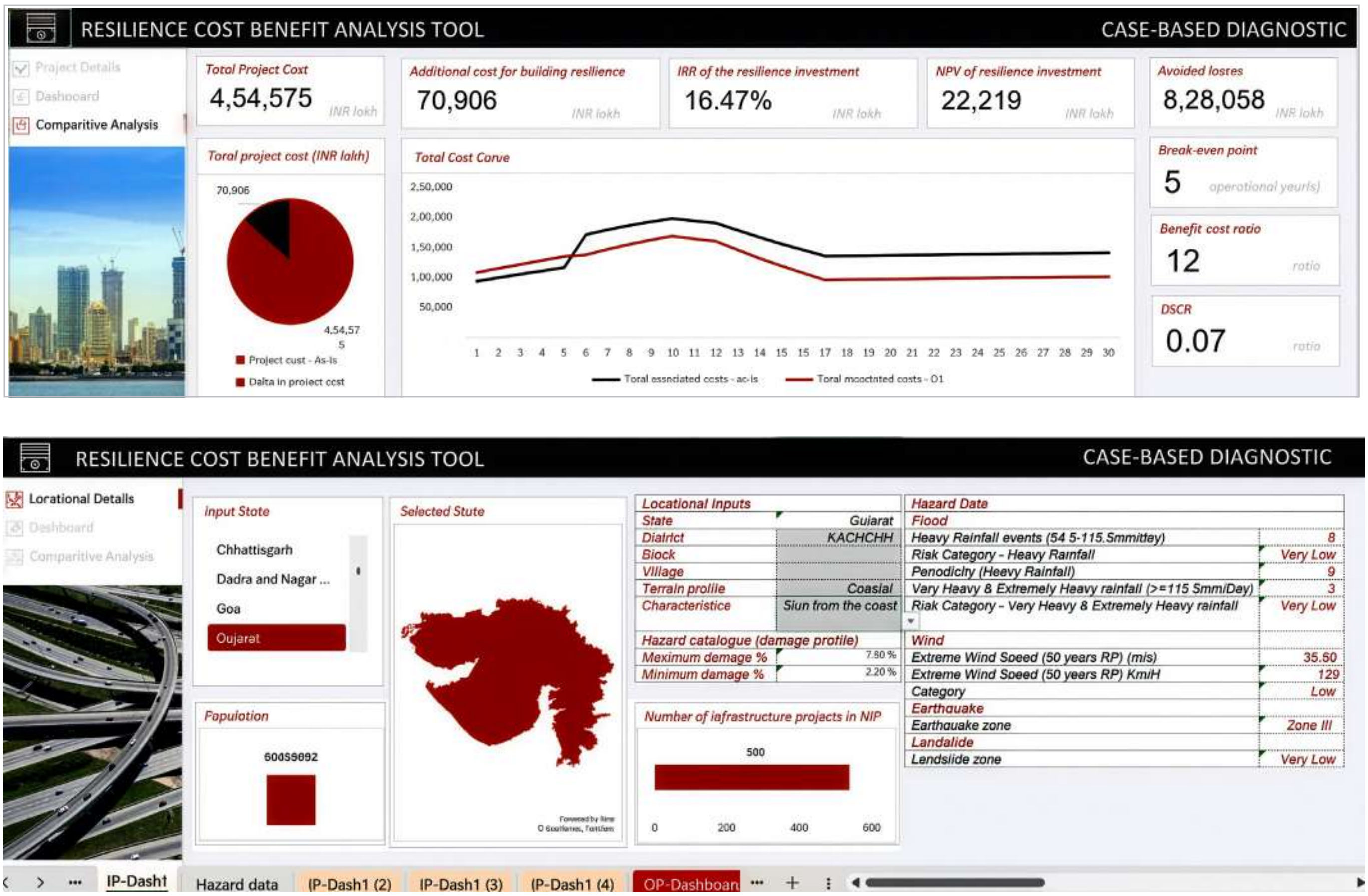


Figure 5: The RCBA tool dashboard

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

Utilize digital monitoring tools [e.g., Decision Support System (DSS)] to track asset performance and receive hazard alerts. A decision support system 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 those 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.

A few examples of individual platforms that can be used to provide data to power a DSS for each of the data parameters are shown in the main report.

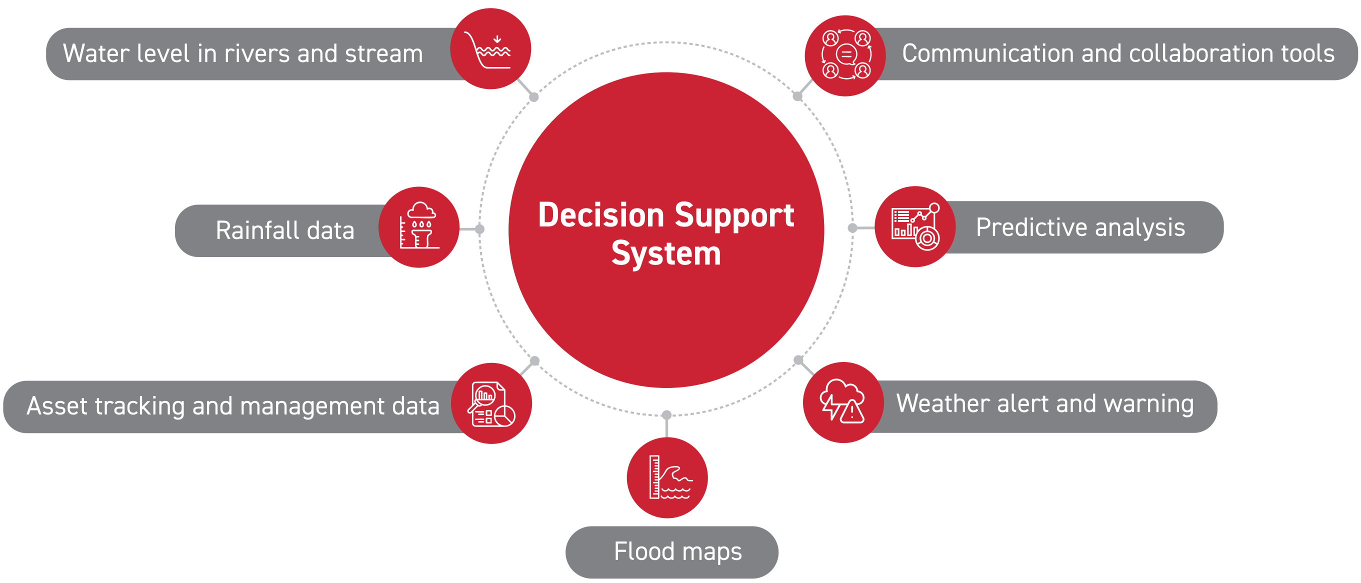


Figure 6: Key parameters for building a decision support system

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:**

  Line ministries, implementing agencies and private stakeholders should be trained through workshops to record and share data on the platform and to use disaster risk information from it for better decision-making.

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

- **The ministries concerned need to mandate natural 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.**

- Projects requiring mandatory HR&VA should be identified using a **Disaster Risk Matrix based on three criteria**—location in a hazard-prone area, economic significance and low network redundancy.

Hazard Profile

Hazard Profile		Economic Significance		Network Redundancy
Parameter		**Parameter**		**Parameter**
Project location in the topmost hazard-prone districts for any of the major hazards: Landslides, floods, cyclones or earthquakes	And	Economic internal rate of return (EIRR) above a certain threshold	Or	Number of alternate routes/infrastructure to the proposed project below a minimum benchmark

Figure 7: Disaster Risk Priority Matrix for selection of projects

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

- The **format for the EFC/ SFC/ PIB/ DIB/ PPPAC 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.

Resilient Projects Appraisal Checklist

Risk

Questions	Remarks
High-level Disaster & Climate Risk screening: Does the project fall in the priority category based on the Disaster Risk Priority Matrix?	

Questions	Remarks
Detailed Risk Assessment: Whether the Detailed Project Report consists of findings from 'Hazard Risk & Vulnerability Assessment'?	
Risk Mitigation/Resilience Measures: What are the resilience measures taken to mitigate the Disaster & Climate risks?	

Return

Questions	Remarks
Financial Returns*: What are the expected financial returns for Resilience measures adopted across the project Lifecycle? (Use the RCBA tool to assess it)	
Economic Returns(Optional):** What are the Economic returns of the resilience measures adopted across the project Lifecycle?	

Value

Questions	Remarks
Adaptation Co-Benefits: What are the Co-benefits of the Resilience measures adopted? (Social Impact, Climate change Mitigation, Biodiversity conservation)	

- **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.

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 accordingly determine the levels of risk and allocate responsibilities among the parties involved, thereby enhancing the overall resilience of infrastructure projects.

**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 infrast ructure damage.*

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 and maintenance (O&M) stages. The resilience expert can also suggest resilience considerations in the O&M manual and 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.
- A detailed checklist outlining resilience considerations specific to various types of infrastructure assets will further empower these experts to effectively evaluate and monitor infrastructure at all 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 and sector-specific checklists have been provided for Resilience Experts in the Guidance document.

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

Suggestive Sector agnostic checklist for the line ministries

Project phase	Checklist	✓/✕	Reference guidance document/ clause
Concept-ualization 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: ■ **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: **Roads:** Temperature variability, precipitation patterns, and heat waves **Railways:** Temperature fluctuation, rainfall and flooding **Power:** Temperature extremes, sea-level rise and coastal erosion		

Figure 8: A snapshot of the Resilience Checklist for Technical Experts

2.5 Financing and 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 National Investment and Infrastructure Fund (NIIF), IIFCL (India Infrastructure Finance Company Limited), or National Bank for Financing Infrastructure and Development (NABFID)].

- **Technical support:**

  NITI Aayog, CDRI and multilateral organizations (such as the World Bank, Asian Development Bank and Asian Infrastructure Investment Bank, 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.

DEA, Ministry of Finance

Develop and update Resilience Taxonomy. (Under overall Climate Finance Taxonomy)

Screen Resilient Infrastructure projects during Appraisal.

Coalition for Disaster Resilient Infrastructure

Provide technical assistance via the initiatives like Infrastructure Resilience Accelerator Fund (IRAF) to operationalize the fund; collaborate with multilateral and international partners.

Financial Institutions (national)

Provide crucial funding and financial expertise e.g.

National Bank for Financing Infrastructure and Development; National Bank for Agriculture and Rural Development (NABARD); National Infrastructure Investment Fund or India Infrastructure Finance Company Limited

MDBs

Offer financial support, technical expertise, and international best practices e.g. World Bank;

International Monetary Fund (IMF); Asian Development Bank (ADB)

Asian Infrastructure Investment Bank (AIIB); New Development Bank (NDB)

Provides advisory support

Housed in relevant Financial Institution

India Infrastructure Resilience Fund (IIRF)

To be accessed by line ministries

Ministry of Roads, Transport and Highways	Ministry of Power	Ministry of Railways
Parastatals e.g. NHIDCL, NHAI	Parastatals e.g. PGCIL, NTPC	Parastatals e.g. DFCCIL, CONCOR

Allocate resilience budgets and access the fund for project implementation.

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

Figure 9: An illustrative structure of the proposed India Infrastructure Resilience Fund (IIRF)

Recommendation 9: Standardize definitions for 'Resilient Infrastructure Investment'

- To enhance market transparency and confidence, government authorities need to standardize the definition of 'resilient infrastructure investments' under India's Climate Finance Taxonomy.
- This will support the private sector, government, multilateral development banks (MDBs) and development finance institutions (DFIs) by providing clear guidelines for identifying and evaluating resilient infrastructure projects.

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 10).
- **Housing institution:**

IRIF could be housed within a government reinsurer such as General Insurance Corporation-RE, with the Ministry of Home Affairs/NDMA being a key stakeholder.

- **Participants:**

Indian States, along with crucial infrastructure stakeholders at the central level, could be key participants in the facility.

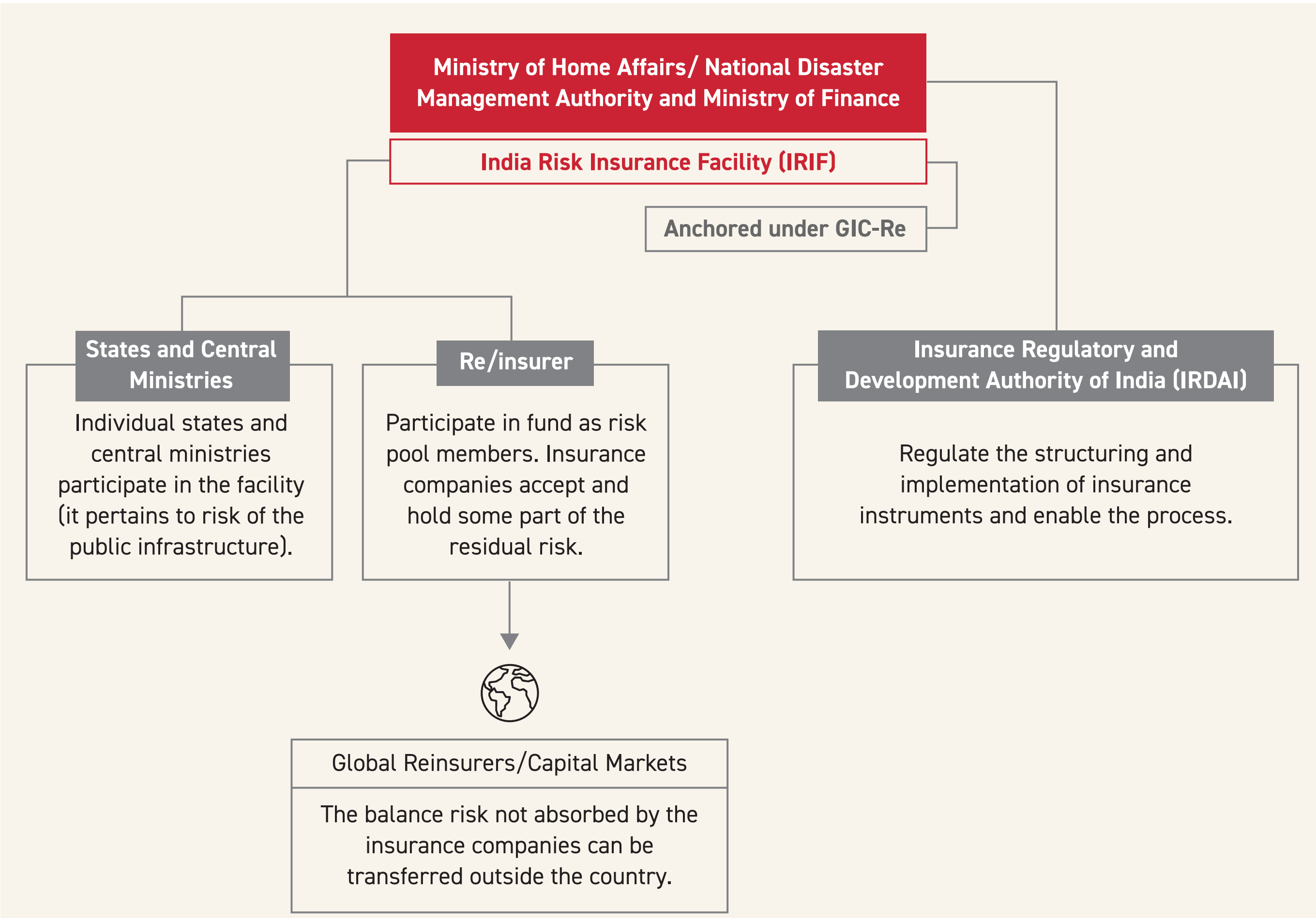
Reinsurers and insurers would also join as members, with insurance companies retaining some risk and transferring the balance to the international market.

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 Insurance-Linked Securities 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.

The idea of a Bharat Nat-Cat pool is under discussion by the NDMA



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

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 with the Department of Financial Services, Ministry of Finance in India, also exploring them as an option.

Priority actions

The study outlines a series of immediate and short-term actions emerging from the findings and recommendations, which are essential for mainstreaming resilience. It requires collaboration between CDRI and government stakeholders, including the Department of Economic Affairs (DEA), relevant line ministries such as MORTH, the Ministry of Power and the Ministry of Railways, as well as implementing agencies and the NDMA's role. The DEA needs to ensure robust funding and approval mechanisms for resilience projects. At the same time, line ministries must integrate resilience into their documents, improve disaster impact documentation, and update codes and standards. The implementing agencies should focus on local-level capacity building and knowledge dissemination. The NDMA will be crucial in managing hazard data governance and establishing a risk insurance facility. This coordinated effort aims to address existing disaster risks effectively and embed resilience across critical infrastructure.

Emerging from the overall study, the following priority action points have been suggested:

1. Scaling up of the RCBA tool through additional data and beta testing
2. Collaboration with foreign national governments for applicability and synergies
3. Modification of the standard bidding documents (SBDs) / model concessional agreements (MCAs) based on suggested changes
4. Appraisal of model documents for other asset types and implementation modalities
5. Standardization of hazard data capturing and documentation with a defined governance mechanism
6. Development of communication and decision support systems with honest data sharing from localized early warning systems
7. Creation of IIRF with identified sources and governance, and ensuring intended utilization through blockchain technology
8. Housing of IIRF in consultation with NDMA and Insurance Regulatory and Development Authority of India (IRDAI)
9. Study of international and Indian insurance and reinsurance markets for disaster risks in the infrastructure sector
10. Risk mapping of Indian states and selected countries for diversified risk portfolios to establish a risk pool

Glossary

Term	Definition
Average Annual Loss (AAL)	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 summarise 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).
Codal Minimums	Minimum parameters that are mandated by the Design code/standard
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).
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).
HRVA (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 aiding communities in making informed decisions to mitigate risks and enhance preparedness (Emergency Program Act, Government of British Columbia, 2021).
Hazard Thresholds	The extent and 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
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 (CBA)	The 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, energy, healthcare, and water sectors, to name a few (UNDRR, 2024).
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).
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)

Term	Definition
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).
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).
Internal Rate of Return	The rate of return at which the net present value of costs and benefits breaks even (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).
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)
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).
Risk	The risk of disasters may be defined as the potential loss of life, injury, or destruction or damage to assets that could occur within a specific period to a system, society, or community, 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).
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).

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