A Compendium of

Good Practices on Disaster Resilient Infrastructure (DRI)

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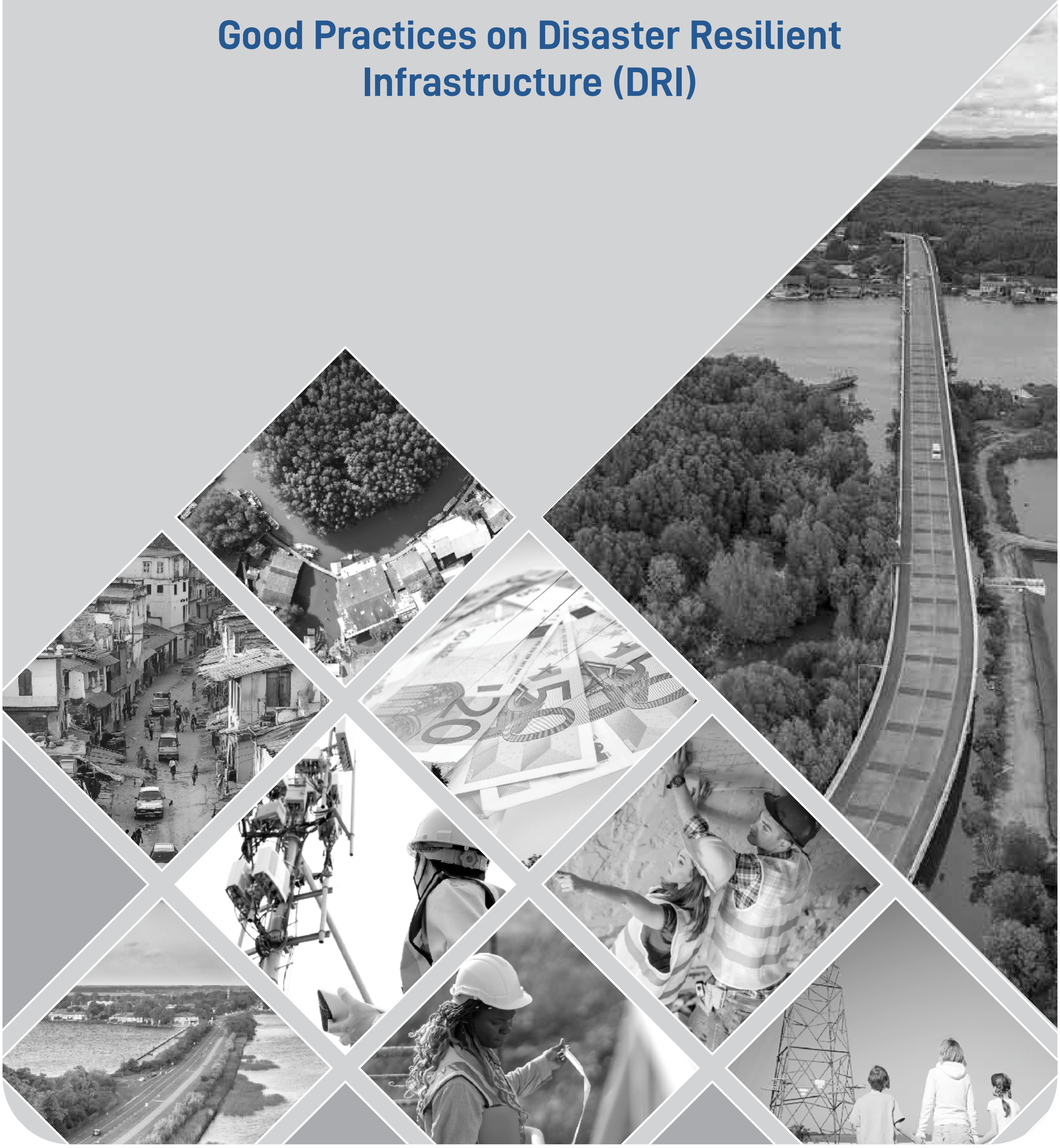

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Table Of Contents

Canada
F8
Jordan
D1
Serbia
D1
Sweden
B3
Norway
A6
European Union
F7
Hungary
D3
United Kingdom
C4
Germany
F2, G5
France
E10
Portugal
A4, F1
Italy
F9
Caribbean Region
C1, C3
Mexico
A2, D1
Costa Rica
F11
Ecuador
D1, G6
Côte d'Ivoire
E7
Ghana
E6
Brazil
E9, G1, G2, G3, G4, G8
Namibia
D1
South Africa
D1, D2
Lesotho
F3
Chile
A5, A7, E5
UAE
F6
Global
E1, E2, E3
India
A1, A3, A8, D1
Nepal
B2
Madagascar
D4, E5
Bhutan
E5, F5
Japan
A10, F4
Bangladesh
E8, D1
Cambodia
A9
Viet Nam
F12
Indonesia
E4
Singapore
A10
Republic of Vanuatu
G7
Tonga
B1, E5
Australia
C2, C5, F10
Country Case Studies
Global Case Studies

List of Case Studies

Message from the G20 Brazil Presidency

The environmental, social and economic challenges associated with increasingly frequent extreme weather events necessitate the implementation of comprehensive political, social and technological strategies aimed at safeguarding individuals and mitigating damage. The development of resilient infrastructure has become an imperative that entails a collective responsibility to foster environments that are resilient and responsive to this reality. This responsibility is intrinsically linked to the guiding priority of the G20 Disaster Risk Reduction Working Group: equity and social justice.

We assert that the reduction of inequalities is synonymous with the reduction of vulnerabilities, thereby empowering at-risk communities and advancing sustainable and inclusive development. Vulnerable populations often encounter significant barriers to accessing essential services such as potable water, sanitation, transportation and electricity, rendering them disproportionately affected by disasters. Investment in resilient infrastructure is essential to ensure that these services are universally accessible, thereby diminishing social disparities and enhancing safety, health, and opportunities.

This document outlines best practices, policies and innovations that fortify the resilience of infrastructure, emphasizing equitable development as a means to cultivate robust communities that are prepared for future challenges, thereby establishing resilience as the cornerstone of our advancement.

G20 Brazil Presidency of Disaster Risk Reduction Working Group

Waldez Goes,
Ministry of Regional Development and Integration

Jader Barbalho Filho,
Ministry of Cities

Acknowledgments

The Coalition for Disaster Resilient Infrastructure (CDRI) wishes to extend its gratitude to the Group of Twenty (G20) Brazil Presidency, G20 Member Countries, invited countries and invited organizations for their response to the call for good practices and their valuable contribution to this compendium. CDRI thanks the Disaster Risk Reduction (DRR) Working Group under the Brazil Presidency for proactively soliciting the case studies presented here.

The cases presented in this compendium demonstrate ongoing and proactive efforts to accelerate actions to implement the Sendai Framework for Disaster Risk Reduction. These case studies highlight the significance of prioritizing disaster resilience across various physical and social infrastructure systems, to reduce disaster-related losses and vulnerability.

For CDRI, this document emerges as a collaborative tool to advocate for and drive a fundamental transformation in the global discourse on disaster resilient infrastructure. With the support of our 47 coalition members – of which 13 are also G20 members – we intend to move from a reactive to a proactive people-centred approach to managing and reducing disaster risk through resilient infrastructure.

In line with the shared mandate of G20 and CDRI, we hope that the good practices compiled in this compendium will be especially useful for infrastructure stakeholders within Least Developed Countries (LDCs), Landlocked Developing Countries (LLDCs), and Small Island Developing States (SIDS).

We thank our experts and peer reviewers: Amir Bazaz (IIHS), Andrea de Bono (UNEP), Arun Sahdeo (USAID), Ede Jorge Ijjasz-Vasquez (Coordinating Lead Author, CDRI's 2nd Biennial Report), Prabir Kumar Das (Studio 1860), Ravi Sinha (Indian Institute of Technology, Bombay), and Rowan Palmer (UNEP), without whose unconditional support this compendium would not have been possible.

We thank the Director General of CDRI, Mr Amit Prothi, under whose guidance this compendium was conceptualized and published.

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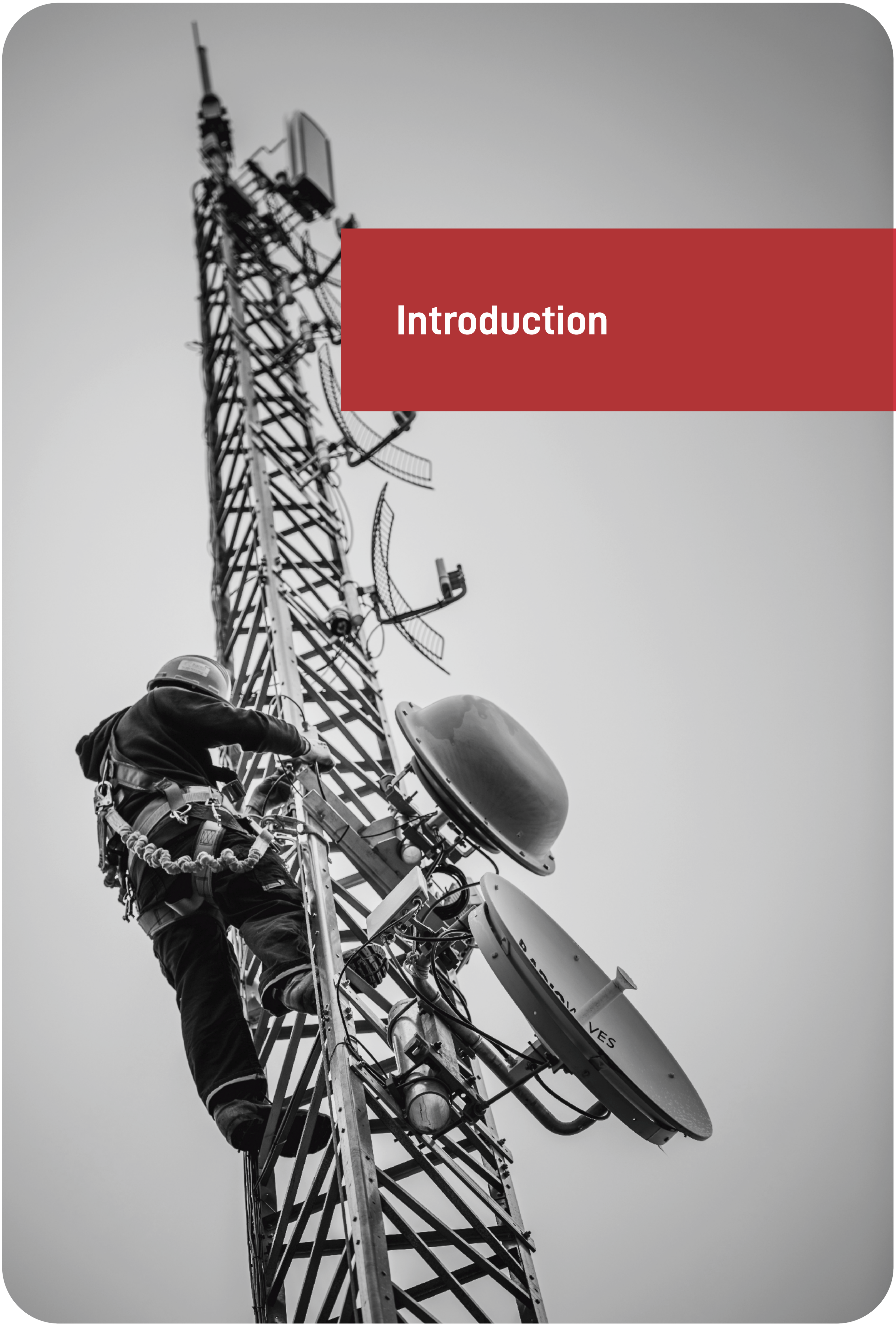


Introduction

Introduction

A Compendium of Good Practices on Disaster Resilient Infrastructure (DRI)

The magnitude and impact of disasters, including extreme weather events, are on the rise worldwide, resulting in unprecedented damage and loss to infrastructure, livelihoods and ecosystems. Taking climate change into account, the total global estimated Average Annual Loss (AAL) due to infrastructure damage is estimated to be between US$732–845 billion, representing about 14 percent of 2021–2022 global GDP growth.[1] Globally, 30 percent of the AAL is associated with geological hazards such as earthquakes, tsunamis and earthquake-induced landslides, and 70 percent with climatic hazards such as cyclonic winds, storm surges, floods, and rainfall-induced landslides. Roads and railways, telecommunications, and power and energy are the sectors that account for around 80 percent of the total AAL of infrastructure sectors. Therefore, while climate change mitigation and adaptation are crucially important, strengthening infrastructure resilience requires an integrated approach that addresses the full range of risk drivers.

The 2030 Agenda for Sustainable Development, endorsed by 193 countries – including all G20 nations – clearly articulates the importance of sustainable and resilient infrastructure systems. However, strengthening infrastructure resilience remains a major global challenge. The impact of climate change and disasters on infrastructure varies between countries, with Least Developed Countries (LDCs), Landlocked Developing Countries (LLDCs), and Small Island Developing States (SIDS) bearing the maximum brunt due to their limited adaptive capacity and resources. Disruption of services due to infrastructure failure in such countries exacerbates inequalities and vulnerabilities.

Investing in DRI can save lives, promote economic growth, and accelerate sustainable development. The G20 nations are committed to advancing efforts towards building infrastructure resilience through the exchange of good practices, technical expertise, collaborative research, and partnerships. Through international cooperation, G20 nations aim to promote principles for quality infrastructure investments (QII) and provide solutions aligned with the needs and strategies of the developing countries, including LDCs, LLDCs and SIDS.

Under Brazil's G20 Presidency, CDRI, in collaboration with the G20 Disaster Risk Reduction (DRR) Working Group,[2] has prepared this compendium of good practices on DRI. The compendium includes 52 case studies from diverse regions and contexts, which offer practical examples and learnings to policymakers, engineers, planners, investors, and other stakeholders for taking actionable steps towards sustainable and resilient infrastructure. The purpose of this compendium is to promote knowledge exchange and sharing through a collaborative process.

At the request of the DRR Working Group, G20 member countries, invited countries, and invited organizations submitted their case studies to the Brazil G20 Presidency and CDRI. In addition, some of the good case studies received by CDRI in 2023 from its various coalition members were also considered for inclusion in the compendium.

All the case studies were reviewed by CDRI with support from various technical experts. Out of 61 case studies received, 52 were shortlisted and included in this compendium. CDRI's internal team reached out to various contributing agencies and countries to gather relevant information and clarifications to finalize each of the case studies. Compiling relevant use cases on DRI is an ongoing initiative of CDRI, and this compendium is being produced as a part of that initiative. The compendium will be further revised to enrich the content and deepen the analysis, and will be disseminated widely across its coalition members and all other relevant stakeholders. Also, the contents and views expressed in the various case studies reflect the opinions of the contributing agencies and are not necessarily the official views of CDRI or the G20 DRR Working Group, Brazil Presidency.

[1] CDRI. (2023). Global Infrastructure Resilience: Capturing the Resilience Dividend: A Biennial Report from the Coalition for Disaster Resilient Infrastructure. New Delhi.

[2] This working group is under the sherpa track of G20. It intends to address the challenges posed by disasters and a commitment to a future where disaster risks are reduced and prevented for all.

This compendium arrives at a pivotal moment, with only five years remaining to achieve the goals set by the Sendai Framework for Disaster Risk Reduction (SFDRR), Sustainable Development Goals (SDGs), and the Paris Agreement. As the global efforts intensify to build resilience and mitigate climate impacts, this volume provides timely insights and practical examples of strategies for resilient infrastructure. It highlights the importance of context-specific solutions and demonstrates that infrastructure resilience requires strategies tailored to local conditions, risks, and capacities. The compendium also demonstrates that a deep understanding of social vulnerabilities and inclusivity has a critical role in achieving infrastructure resilience.

The selected case studies have been categorized into seven overarching themes that illustrate the functional dimensions and perspectives on infrastructure resilience and discuss challenges and lessons learned. A separate section has been added at the end of this compendium, where detailed definitions of several important words used in each of these case studies have been given as per CDRI's DRI Lexicon. The learnings emanating from these case studies have applicability in similar contexts. The thematic sections are as follows:

A. Building Infrastructure Resilience through Sector-Specific Interventions

This theme highlights sector-specific interventions for enhancing resilience. It covers tailored interventions for different types of infrastructure sectors, such as power, transportation, stormwater management, and social infrastructure like schools. The case studies demonstrate how investments in research and capacity development, early warning systems for infrastructure assets, and risk assessments of infrastructure assets (such as airports, metro systems, roads, bridges and power) can contribute towards building resilience of the infrastructure.

B. Embedding Resilience through Post-Disaster Reconstruction of Infrastructure

This theme examines how to incorporate resilience into rebuilding efforts after a disaster. It emphasizes integrating lessons from past events to strengthen infrastructure and prevent future vulnerabilities and impacts. Rebuilding after disasters provides an opportunity to embed long-term resilience into infrastructure, fostering sustainable recovery. The case studies under this theme demonstrate how improved designs and retrofitting based on updated codes can lead to resilient recovery.

C. Financing for Infrastructure Resilience

Recognizing that financial constraints can impact resilience efforts, this theme explores various funding mechanisms and investment strategies for building and maintaining resilient infrastructure. The case studies under this theme feature innovative tools and financial mechanisms such as insurance and the role of the public and private sectors in scaling up resilient infrastructure financing efforts.

D. Nature-based Infrastructure Solutions (NbIS) for Resilience

This theme includes case studies that highlight the use of nature-based solutions to enhance infrastructure resilience. It highlights how natural systems such as wetlands and forests are integrated into infrastructure planning to provide environmental and structural benefits. Nature-based solutions such as micro-forests, community gardens, and swales offer cost-effective solutions for protecting infrastructure while supporting biodiversity, enhancing community engagement, and promoting food security.

E. Risk Assessments and Stress Testing of Infrastructure Systems

This theme explores methodologies for risk assessment of infrastructure systems from geohazards and climate-induced shocks and stresses. Thorough risk assessments during the project planning stages enable anticipation of potential failures of infrastructure systems, and allow for proactive adaptation to build resilience.

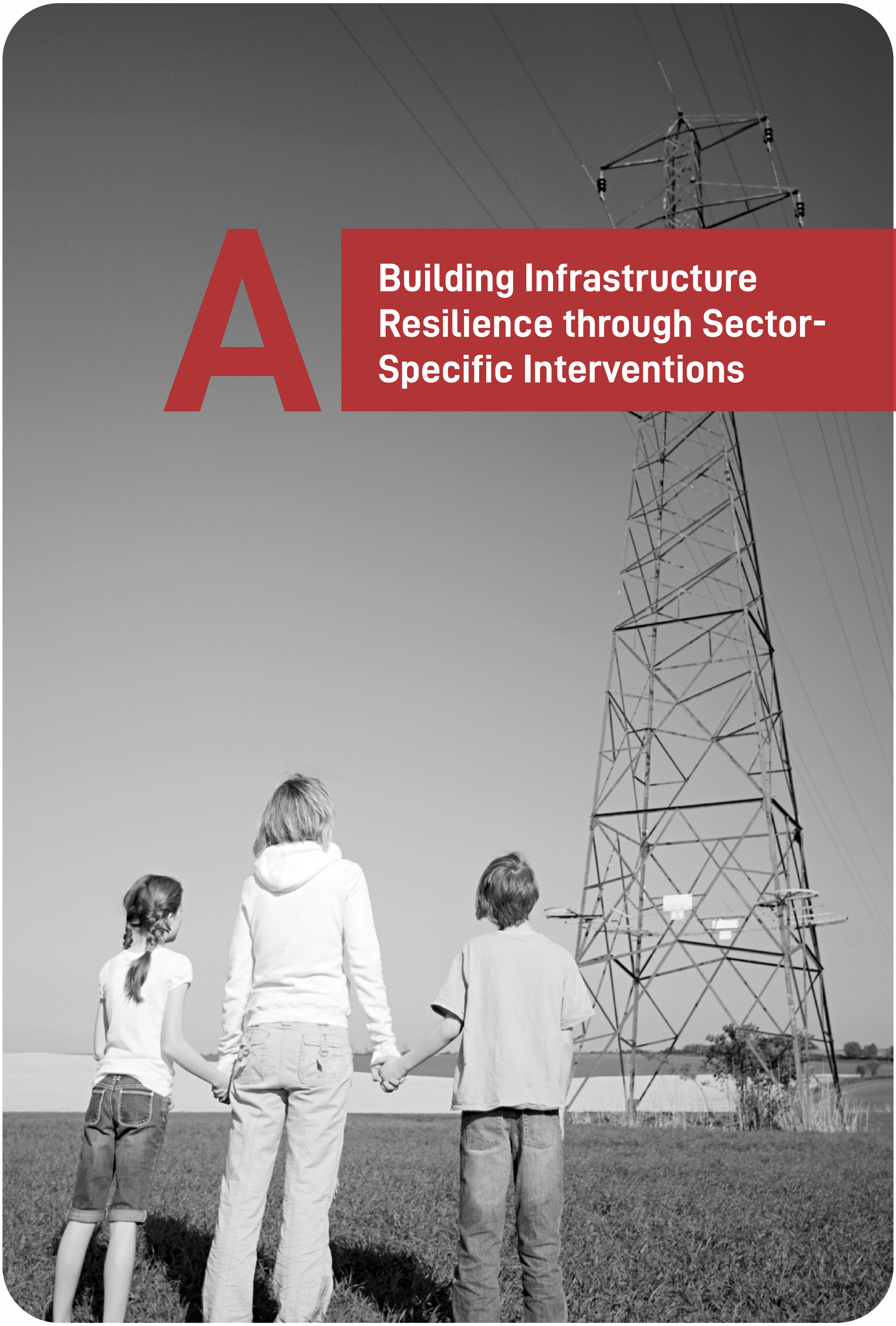
F. Strengthening Institutional Governance for Infrastructure Resilience

This theme addresses the role of governance in promoting infrastructure resilience. It covers developing and implementing codes, standards and policies that guide resilient infrastructure practices and ensure compliance across different regions. These case studies demonstrate that strong institutional governance and adherence to updated codes and standards are crucial to ensuring infrastructure resilience.

G. Infrastructure for Social and Economic Resilience

This theme demonstrates that incorporating the perspectives of equity and social justice into infrastructure development is not just an ethical imperative but a practical necessity. The case studies featured under this theme demonstrate how infrastructure development can lead to social and economic resilience by tailoring infrastructure solutions to local conditions, ensuring community participation, and prioritizing infrastructure investments that protect and support vulnerable groups.

To sum up, this compendium is a rich repository of practical examples, learnings, and replicable solutions that can help stakeholders worldwide in designing and implementing disaster-resilient infrastructure projects that are better equipped to face future disasters. CDRI believes that this compendium will be an opportunity to strengthen the agenda of the G20 DRR Working Group, which is to consolidate and disseminate knowledge to empower developing countries including LDCs, LLDCs and SIDS to plan and invest in DRI as a cornerstone of a sustainable future.



A

Building Infrastructure Resilience through Sector-Specific Interventions

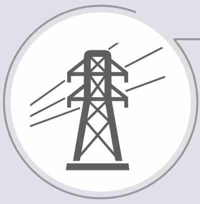
Given the rising trend of climate-induced disasters, building resilience of infrastructure across various sectors is likely to yield a significant return on investment: approximately four times of the cost incurred, thus safeguarding economic growth and community well-being. In this section the compendium explores sector-specific interventions from 11 case studies, revealing the lessons learnt and identifying transferable solutions that may be viable in similar settings with contextual adaptation. Sectors such as transportation, power, urban infrastructure, and early warning systems for water infrastructure have been covered.

Transportation Sector (Airport, Road, Rail Transit Systems)

The cases of Japan's Kansai Airport and Changi Airport in Singapore demonstrate the significance of data-driven risk assessment and scenario modelling for disaster preparedness. These airports have been heavily impacted by typhoons and flood-related incidents, highlighting the need for robust resilience strategies.

Metro systems in India, often referred to as the "lifelines of the city," also demonstrate a comprehensive approach to resilience. Metro construction in both Delhi and Chennai considers multi-hazard risk assessment and applies relevant codes and standards to make the metro system disaster resilient. Further capacity development of professionals was undertaken to ensure implementation of resilience measures throughout the project's lifecycle.

Rural road development in Cambodia focused on the importance of investing in innovative research to improvise and develop technical safety standards.



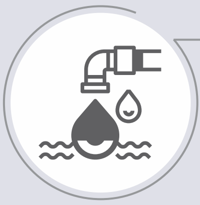
Power Sector Infrastructure

The disaster-resilient power system case study from Odisha in India provides an account of the study conducted on disaster resilience strategies for the power sector – specifically transmission and distribution infrastructure – against cyclones and floods. The study included risk assessment, as also a review of codes and standards, governance, the policy landscape, and investment mechanisms.

While risk assessments are widely recognized for their importance in rating disaster preparedness, they also play a crucial role in determining the location of critical infrastructure. Mexico's study on floating solar power plants demonstrates how these assessments can be used to identify suitable locations for infrastructure development and mitigate potential risks.

Social Sector Infrastructure

The application of non-structural seismic reinforcement measures by public schools in Portugal demonstrates the significance of cost-effective initiatives in the sector. These initiatives, such as developing school safety guidelines, conducting thorough assessments to identify deficiencies, and disseminating effective corrective measures to all relevant stakeholders, can help in creating safe schools.



Water Supply and Drainage Infrastructure

In Chile, innovative stormwater management systems and alluvial flood protection schemes have been designed to address flood issues by integrating future climate projections into their design. These systems incorporated updated geotechnical, structural, and hydraulic information combined with natural water retention methods, effectively reducing the impact of climate-induced flood events in the cities.

Real-time monitoring and early warning systems, such as the cloud-based e-Aabhas software developed by India's NHPC Limited, are indispensable for embedding disaster resilience in the infrastructure sector. These systems can provide timely warnings against flood risks, enabling governments and communities to take appropriate action.

Similarly, in Norway, the resilience of masonry dams has been improved through a simple structural modification and the installation of an automatic lake level monitor that allows for early detection of threats and prompt response to potential failures. These examples highlight the need for infrastructure to be robust and adaptable, particularly in high-risk environments.

Key Takeaways

- Planning, design and construction of infrastructure should be informed by data-driven risk assessment.
- Building the capacity of policymakers, infrastructure professionals, regulators, businesses and communities is crucial for embedding resilience across various infrastructure sectors.
- Real-time monitoring and early warning systems can build infrastructure resilience and enhance the preparedness of governments and communities.
- Both structural and non-structural measures contribute towards infrastructure resilience.

A1: Implementation of Early Warning System at NHPC, India

India

Submitted by:
NHPC Limited, Government of India

Introduction to the Initiative

Hydropower projects located in the Himalayan regions of India are highly vulnerable to multiple disasters such as landslides, cloudbursts, flash floods, earthquakes, avalanches, glacial lake outburst floods (GLOFs) and landslide lake outburst floods (LLOFs). Falling rocks also occasionally block the flow of water in the stream, creating an artificial lake. The sudden breach of this artificial lake can trigger devastating flash floods. To reduce the risk to life and property from such disasters, a comprehensive Early Warning System (EWS) is needed.

NHPC Limited is an enterprise under the Ministry of Power, Government of India (GOI), has launched an innovative Early Warning System for its hydroelectric projects. This cloud-based software application enables real-time monitoring of river water levels and discharges, receives inputs in form of Application Programming Interface (API), and works in collaboration with various expert agencies such as the Indian Meteorological Department (IMD) and the National Disaster Management Authority (NDMA), providing crucial alerts to project authorities and local communities during flood events.

The initiative has significantly enhanced disaster preparedness and response, reducing loss of life and property in vulnerable regions. By integrating advanced telemetry and forecasting technologies, NHPC's EWS exemplifies good practice for proactive flood management, enabling timely evacuations and safety measures.

Detailed Description of the Initiative

Sector Coverage

The EWS initiative by the NHPC is a significant development in the hydroelectric power sector in India. This sector is crucial for the country's energy security and sustainable development, making the implementation of such systems vital for both operational efficiency and community safety.

Background and Need for the Initiative

Flood events pose a substantial risk to hydroelectric projects, which are often located in river basins and mountainous regions prone to heavy rainfall and sudden water level changes. The need for the EWS arose from the necessity to enhance disaster preparedness and response capabilities. Floods can cause severe damage to infrastructure, disrupt power generation, and endanger the lives of local communities. Therefore, a system that provides real-time monitoring and issues alerts is essential to mitigate these risks and ensure the safety and reliability of hydroelectric operations.

Implementation and Cooperating Organizations

The initiative was spearheaded by the NHPC Ltd. under the guidance of Central Electricity Authority and Ministry of Power. NHPC is a leading organization in India's hydroelectric power sector. NHPC has leveraged the expertise of various specialist agencies to implement the EWS effectively. Key contributors include the IMD and NDMA, whose inputs have been crucial in developing a robust and reliable system.

The e-Aabhas software, the core of NHPC's EWS, is a secured cloud-based platform integrating advanced telemetry and forecasting technologies to monitor river water levels and discharges. The system's foundation includes automatic water levels and velocity sensors with telemetry installed at upstream locations. Data from these sensors is transmitted via API to the e-Aabhas software. Developed in-house by NHPC's Hydrology and IT departments, the system leverages expertise from various agencies. The Indian Meteorological Department (IMD) provides 7-day weather forecasts, extended rain forecasts, flash flood warnings, and heavy rain forecasts. The National Disaster Management Authority (NDMA) offers RSS feeds for disaster-related information. These inputs are essential for the system's accuracy and reliability.

NHPC is actively collaborating with other organizations to enhance the EWS. The Central Water Commission (CWC) will contribute long-term inflow forecasting; the National Remote Sensing Centre (NRSC) will focus on glacial lake monitoring; the Defense Geoinformatics Research Establishment (DGRE) will provide expertise on landslides and avalanches; and the Centre for Development of Advanced Computing (CDAC) will develop comprehensive EWS models specifically for the Teesta Basin. These partnerships aim to incorporate cutting-edge technologies, such as advanced data analytics and machine learning, to improve the system's predictive capabilities and overall performance.

The system's nerve center is a Master Control Room (MCR) equipped with advanced technology. Since August 2022, this facility has been operational 24/7, featuring cloud-based software, data storage, communication tools (SMS, email, bulk calling, WhatsApp), ICT equipment, alert systems, a centralized control room, video wall, and dedicated personnel. By pooling resources and expertise, NHPC has ensured a state-of-the-art EWS that provides timely and accurate flood warnings, safeguarding both infrastructure and communities.

What Was Done

Sensor Stations (SS) consisting of radar type water level and velocity sensor, and a solar hybrid power supply system and communication (VSAT or cellular or both) infrastructure, have been installed on rivers upstream of dam sites. River water levels from all the Sensor Stations are relayed on a real-time basis simultaneously to both the Central Command and Control Station (CCCS) located at the dam site and the MCR, located at Faridabad.

Both the CCCS and the MCR are provided with IT infrastructure to process the data received from the Sensor Stations, generate alerts and warnings based on preconfigured settings, and disseminate such warnings to the target population through multiple modes like sirens, public address system, cellular communication, Voice over Internet Protocol (VoIP), and Very Small Aperture Terminal (VSAT). In addition, CCTV cameras are installed at the dam sites and important locations for visual monitoring of river flow.

Impact on Reducing Vulnerabilities and Inequalities

The implementation of the EWS has significantly enhanced disaster preparedness and response capabilities in regions vulnerable to floods. By providing timely alerts and enabling proactive evacuation and safety measures, the system helps protect at-risk populations, saving precious infrastructure and equipment. Additionally, the system's real-time monitoring capabilities enable authorities to make informed decisions and allocate resources more effectively during flood events.

The EWS also contributes to reducing inequalities by ensuring that all communities, regardless of their location or socioeconomic status, have access to timely and accurate information. This is particularly important in remote areas, where access to information and resources may be limited. By providing equal access to early warnings and safety measures, EWS helps bridge the gap between different communities and ensures that everyone has the opportunity to protect themselves and their properties.

Master control room for EWS at NHPC, Faridabad

Learnings and Impact

Implementation Challenges and Mitigation

- **Establishing Sensor Networks:** Setting up sensor networks was challenging due to remote locations and accessibility issues. The sensors often became faulty due to extreme climatic conditions, such as heavy snowfall, landslides, and extreme temperatures.
- **Communication and Power Issues:** Ensuring uninterrupted communication and power availability was difficult. Remote locations often lacked reliable power sources and communications infrastructure, making it hard to maintain continuous operation of the EWS. Furthermore, in adverse conditions, Global System for Mobile Communications (GSM) networks and power systems sometimes stopped working, disrupting the automatic transmission of data to MCR and Central Command and Control Station (CCCS).
- **Land Acquisition:** Acquiring private and government land for sensor installation remains a challenge and is a time-consuming process. Obtaining clearance for installing sensors on various structures, such as bridges, also takes time.
- **Permissions:** In some locations, establishment of EWS requires permission from the GOI or defence establishments, as most vulnerable projects are located in border areas. This is a time-consuming process.
- **Collaboration with Agencies:** Collaboration with other agencies was difficult. However, this has been facilitated by proactive measures from the Ministry of Power, GOI, which signed Memorandums of Understanding (MOUs) with various agencies under different ministries. This helped in pooling resources and expertise.
- **Equipment Specifications:** The specifications of equipment and sensors were decided based on experience and the unique climatic conditions of the Himalayan region. This included considerations for durability and reliability in harsh environments.
- **Evolving Technology:** The technology in the field of EWS is still evolving. Continuous advancements are needed to improve the accuracy, reliability, and efficiency of these systems. Additionally, standardizing various types of sensors from different manufacturers has proven to be a significant challenge.
- **Integration with Meteorological Data:** The system was integrated with real-time inputs from the IMD to enhance forecasting and alert capabilities. Ascertaining runoff corresponding to rainfall is still a challenge.

- **Training and Capacity Building:** Training local staff and building capacity to operate and maintain the EWS was essential. This included regular training and discussion to ensure that the personnel were well-equipped to handle the system.
- **Maintenance and Upgradation:** Regular maintenance and upgradation of the system were necessary to ensure its optimal performance. This included periodic checks, software updates, and replacement or maintenance of faulty sensors.
- **Community Awareness and Preparedness:** Raising awareness and preparedness among the local communities was crucial. This involved conducting drills and educational programs to ensure that the communities knew how to respond to warnings and take necessary precautions.
- **Lack of Awareness:** The lack of awareness among the affected/local population often results in significant resistance and delay in the implementation of the EWS.
- **Lead Time:** Suitable lead times for alerts are not available at all locations, which can hinder the effectiveness of EWS.
- **Vandalism and Theft:** Vandalism and theft of installed EWS equipment can severely compromise the system's effectiveness. Implementing robust security measures and engaging the community can help mitigate these risks.
- **Budget Allocation:** Allocating a budget for the installation of the EWS was challenging due to a lack of knowledge in the early stages and no initial budget allocation.
- **Limitations:** The development of the EWS system was slow in the initial phases due to a lack of clear understanding, proper direction, guidelines and understanding.

Lesson Learned from Implementation

- **Underestimation of Risk:** Flood risks are often underestimated, leading to insufficient preparedness and response measures. Accurate risk assessment and awareness are crucial for effective flood management.
- **Need for Redundancy:** Given the high stakes involved, redundancy in every component of the system is essential. This includes backup power supplies, communication channels, and data collection instruments to ensure continuous operation during critical times.
- **Challenges in Remote Locations:** Providing reliable power and communication in remote or adverse locations remains a significant challenge. Innovative solutions, such as solar power and satellite communication, are needed to overcome these obstacles.
- **Data Interpretation:** Interpreting disaster-related data from diverse fields and expert agencies can be complex. Effective collaboration and integration of data from various sources are necessary for accurate and timely warnings.
- **Capacity Building and Quality Alert:** Effective action at disaster sites requires not only high-quality alerts but also a clear understanding of those alerts, which necessitates extensive training for people in disaster-prone areas.

Scalability

The system is scalable, and around 300 project/power stations can be provided with alerts with minimal effort and cost at present.

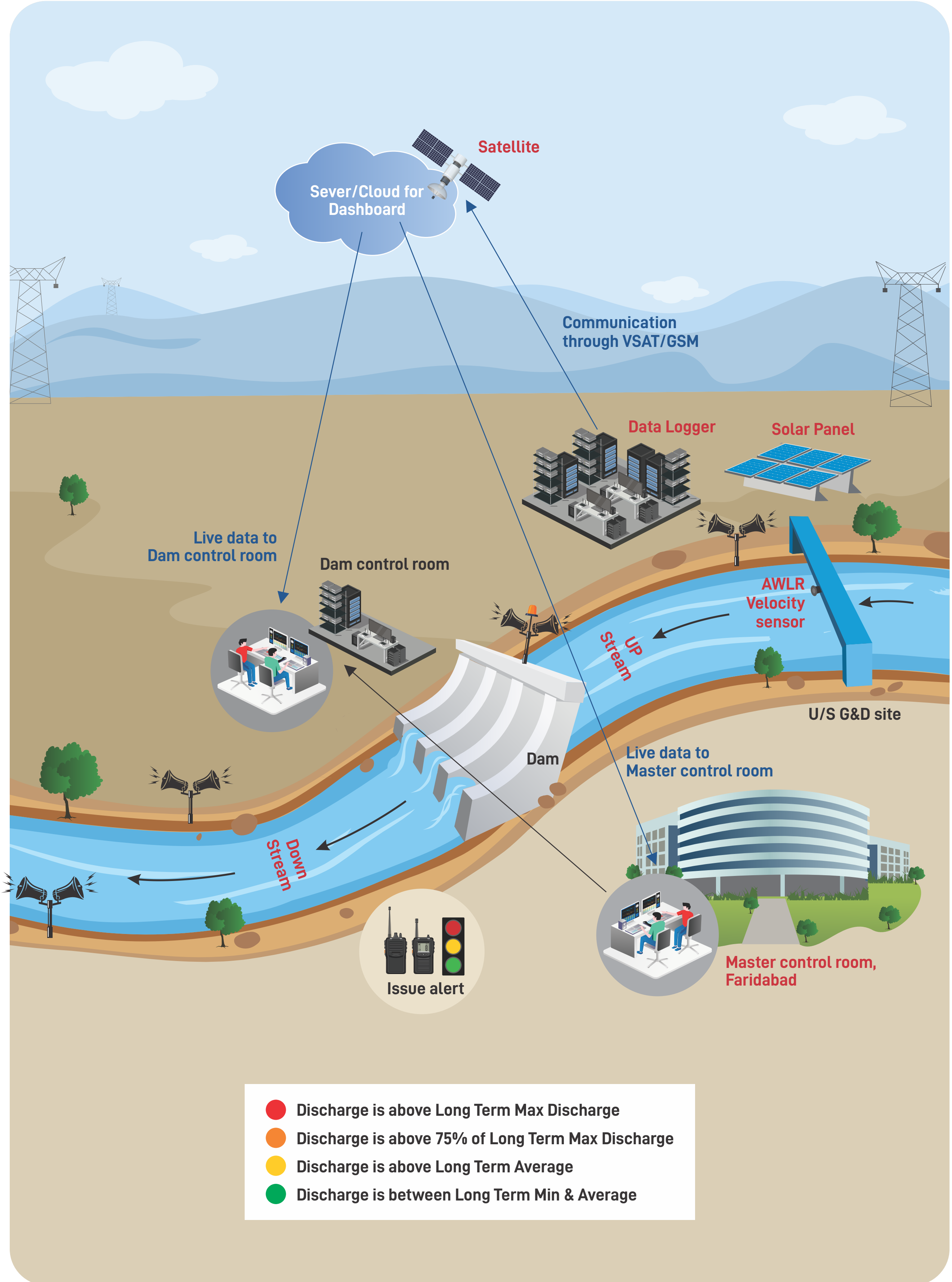
Co-benefits

All upcoming and existing projects can access advanced information in a coordinated manner at a reduced cost through cost-sharing among developers. A mechanism for implementing this cost-sharing model needs to be established.

Way Forward

Moving forward, NHPC plans to further enhance the EWS by integrating more advanced technologies such as artificial intelligence and machine learning for better predictive capabilities. Continuous collaboration with expert agencies and local communities will remain a priority to ensure the system's effectiveness and reliability. Additionally, expanding the system's coverage to include other natural disasters, such as landslides, avalanches and earthquakes could provide comprehensive disaster management solutions, further safeguarding vulnerable populations and infrastructure. Integration of other developers in MCR is also in process.

Figure A1.1: Early Warning System Framework



Additional Information

Readings

NDMA. (2020). NDMA guidelines for GLOF and LLOF management.
https://ndma.gov.in/sites/default/files/PDF/Guidelines/Guidelines-on-Management-of-GLOFs.pdf

Ministry of Law and Justice, Government of India. (2021). The Dam Safety Act, 2021.

Central Electricity Authority. (2021). Report of the Committee to decide upon Early Warning System to be put in place in the hilly regions.

Central Electricity Authority. (2022). Standard Operating Procedure for Early Warning System in Vulnerable Hydro Projects.

Mittal A., Saini V.K., Mishra M., Srivastava S. & Shukla Bhavya. (2022). Early Warning System in Hydropower Projects with a Case Study of its successful implementation in Rangit IV HEP. International Dam Safety Conference, Jaipur, India.

GoI. (n.d.) Flood Early Warning System – A Warning Mechanism for Mitigating Disasters During Flood. Department of Administrative Reforms & Public Grievances.
https://darpg.gov.in/sites/default/files/70.%20Flood%20Early%20Warning%20SystemFLEWS-Documentation-Final.pdf

Mishra M., Shukla S.D. & Srivastava S. (2023). Use of Disruptive Technology in Development of Comprehensive Early Warning System for Subansiri Lower HE Project of NHPC. The Institution of Engineers Conference, Assam, India.

Central Electricity Authority. (2024). Standard Operating Procedure for Early Warning System in Hydro Projects.

A2: The Construction of a Floating Solar Power Plant, Mexico

Mexico

Submitted by:
Ministry for Europe and Foreign Affairs, Government of France

Introduction to the Initiative

The project is a 120 MWp floating solar power plant in Mexico, financed by a €150 million non-sovereign loan to Comisión Federal de Electricidad (CFE). It focuses on the energy sector and contributes to Mexico's objectives of increasing its renewable energy capacity. The total project budget is US$167 million.

Detailed Description of the Initiative

Mexico has over a hundred hydroelectric power plants with a total capacity of 12.6 GW, representing 14.4 percent of installed capacity by 2022. These plants have varying load factors depending on the season and time of day and can even be low in certain watersheds with less favourable hydrology. This low utilization rate makes it possible to combine these facilities with photovoltaic generation facilities, which are highly complementary.

In Mexico, the potential installed capacity of floating solar power plants is estimated at 18 GW, including 2.2 GW on dams operated by the CFE. In the short and medium term, these dams represent an opportunity for CFE to rapidly increase its investments in solar photovoltaic power on federal property, and thus contribute to the national targets for renewable energy (50 percent of the mix by 2050).

The project aims to increase electricity production capacity from renewable energies by supporting CFE in the development of Mexico's first floating solar power plant project, with a strong replicative dimension. The investment project has been entrusted by CFE to Fideicomiso de Energias Limpias (FIDE), which will sign a contract with a single service provider through an open international bidding process, complying with the Mexican Public Procurement Code.

Site selection (El Fuerte) was based on a multi-criteria analysis of 23 hydroelectric plants, taking into accounts technical attributes (reservoir, electrical equipment, network, etc.), socioenvironmental factors (physical environment, biological criteria, human environment, etc.) and climatic aspects (current and future risks). The feasibility study will include a resilience study of the floating solar power plant and propose adaptation measures to address relevant infrastructure risks.

The National Institute of Ecology and Climate Change (INECC) characterizes the vulnerability of the El Fuerte dam to water stress as medium in its current state, but very high in the future, regardless of the chosen scenario. Water level readings recorded on the dam over the last 16 years show an insufficient level (below the minimum operating level) on six occasions.

Learnings and Impact

The site and the region are subject to current (high vulnerability) and future (very high vulnerability) water stress. In the future, this stress will threaten the proper operation of the hydroelectric plant and water access for the population. The PV plant will save water, particularly in the dry season (low cloud cover), and plays a counter-cyclical role in relation to hydroelectricity. It therefore provides an adaptation service for the local electricity system, avoiding the risk of loadshedding in the event of drought and saving water for the population.

A3: Disaster Resilient Power Systems for Odisha, India

India

Submitted by:
GRIDCO Limited, India

Introduction to the Initiative

A reliable, affordable and resilient power system plays a crucial role in the overall development of a region. The Disaster Resilient Power Systems for Odisha project evaluated the disaster preparedness and resilience of the power system in the state of Odisha, India, focusing on the state's transmission and distribution infrastructure. The project was a collaborative effort involving the Odisha state government, the National Disaster Management Authority (NDMA), CDRI, the Odisha State Disaster Management Authority (OSDMA), and the state power sector stakeholders.

The project set the agenda for developing resilient future power infrastructure and upgrading the existing infrastructure in Odisha. The key findings included the importance of risk mapping, updating design codes and standards, and establishing better regulatory and financial mechanisms. The project thus serves as a valuable case study for other regions and stakeholders to assess the disaster preparedness and resilience of their power systems.

Detailed Description of the Initiative

India is highly vulnerable to natural hazards such as cyclones, tsunamis, earthquakes, and floods, with significant portions of its land and coastline exposed to these risks. Odisha has a 480-kilometer coastline along the Bay of Bengal and is frequently impacted by cyclones and floods.[3,4] In the past five decades, Odisha has been affected by more than 17 floods and over 7 cyclones. These natural hazards have caused extensive damage to Odisha's power infrastructure, leading to prolonged power outages and disruption to the state's economy and society.

The rising frequency and severity of hazard events due to climate change underscored the urgent need for a resilient power system infrastructure to reduce regional vulnerability against future disasters. To address this urgent need, a collaborative project was initiated with support from NDMA, involving CDRI, GRIDCO Ltd, the Department of Energy, the government of Odisha (power, finance, and disaster management departments) and the state power transmission and distribution utilities. The project received support from the Ministry of Power (MoP) and the Central Electricity Authority (CEA). The study evaluated the vulnerability of the state's entire transmission and distribution (T&D) infrastructure to cyclones and floods along its coastline.

The project was divided into two phases:

- Phase I focused on preparedness and survival, recovery and reconstruction, and social and community resilience. The initiative documented existing preparedness strategies and survival mechanisms used to protect Odisha's power infrastructure from natural hazards. The study also analyzed Odisha's post-disaster repair and replacement processes for damaged equipment and infrastructure. The study utilized available literature, conducted consumer impact surveys, focus group discussions (FGDs), key informant interviews (KIIs), and questionnaire-based surveys. A comprehensive list of state-level learnings and recommendations for each of the sections in the study was developed. Some of these recommendations are based on the outcomes of stakeholder and community engagements in the immediate aftermath of Cyclone Fani, which

[3] Singh, D., & Jeffries, A. (2013). Cyclone Phailin in Odisha, October 2013: Rapid damage and needs assessment report. Government of Odisha.

[4] Patel, S. K., Mathew, B., Nanda, A., Pati, S., & Nayak, H. (2019). A review on extreme weather events and livelihood in Odisha, India. Mausam, 70(3), 551-560.

hit the coasts of Odisha in 2019. Some of the recommendations include leveraging liquidity funds through annual allocation of revenue, the need for drone-assisted damage assessment, GPS-enabled workforce structuring, state-specific designs and specifications, and the use of parametric insurance and CAT bonds.

- Phase II encompassed risk identification and estimation; updating codes, standards, and regulations; integrating technology and innovation; and developing policies to enhance power infrastructure resilience. Cyclone wind speed and flood-water levels in the region were simulated using mathematical models, which were used to assess the exposure of power infrastructure assets against these levels. A set of vulnerability indicators were later developed to assess the vulnerabilities of these assets. Critical assets such as lines supplying power to hospitals, cyclone shelters, and trunk lines were identified. Additionally, the distance of the assets in relation to the coastline was mapped. Together with criticality, vulnerability, and coastal proximity, the assets were categorized to determine where interventions should be prioritized. The study also examined the existing design standards and codes for the assets, assessed their limitations, and recommended ways in which they could be improved. This phase also focused on ensuring that Odisha's power sector could withstand future disasters through improved governance, capacity building, and financial preparedness.

The initiative will directly contribute to reducing vulnerabilities by enhancing the resilience of Odisha's power infrastructure, especially in cyclone-prone coastal areas. By systematically prioritizing assets, the initiative aims for more effective and targeted resource allocation, reducing the risk of prolonged outages and ensuring faster recovery after disasters. The implementation of disaster-resilient practices and the integration of innovative technologies into the power sector's operations further reduced the risk to vulnerable populations and of associated economic and social disruptions during disasters. The initiative has set a precedent for other states in India, providing a model for disaster preparedness and resilience that can be adapted to local contexts, helping to reduce vulnerabilities and inequalities across the country.

The six-volume study reports were released at a high-level gathering of senior representatives

Learnings and Impact

Challenges

The project faced certain challenges in the GIS mapping of power infrastructure assets due to requirement of complex data from the stakeholders. The team had to individually map assets, use proxy data, and rely on existing literature to identify assets and assess past damage. Another major obstacle in the field was the lack of coordination among different organizations within the state due to the fragmentation of information on disaster management strategies. The study mapped existing coordination pathways and identified strategies for improved collaboration across multiple agencies and stakeholders.

Benefits

- **Disaster Preparedness:** The initiative led to the development of a toolkit titled "Disaster Resource Inventory for the Power Sector (DRIPS)". DRIPS allows states and organizations to access available resources nationwide, leading to better resource management and quicker recovery times during disasters. This toolkit will improve data visibility and facilitate swift decision-making for disaster mitigation, and enhance disaster preparedness and response capabilities in Odisha and at the national level. Additionally, the project has supported utilities and the renewable energy sector by developing an advisory on disaster preparedness for power utilities and renewable energy plants facing cyclones and high wind speeds.
- **Codes, Standards, Regulation and Financing:** The study highlighted the urgent need to update codes, standards, regulations, and financial mechanisms to create a more resilient and efficient power infrastructure that is better equipped to withstand future disasters. The study developed a set of vulnerability indicators, including age of structure, past damage history, and proximity to the coast, to assess the vulnerability of individual power infrastructure assets.
- **Resilience:** Adopting the recommendations and practices outlined in the project would reduce the time required to restore power after a disaster. The initiative will also directly benefit local communities by minimizing disruptions to social and economic activities and essential services.
- **Informed Decision-Making:** The systematic documentation of Odisha's experiences and the development of resilience strategies provided valuable insights for policymakers and governments at both state and national levels. These insights will help in informed decision-making, particularly regarding resource allocation, infrastructure development, and disaster management policies.

Scalability

The project faced certain challenges in the GIS mapping of power infrastructure assets due to requirement of complex data from the stakeholders. The team had to individually map assets, use proxy data, and rely on existing literature to identify assets and assess past damage. Another major obstacle in the field was the lack of coordination among different organizations within the state due to the fragmentation of information on disaster management strategies. The study mapped existing coordination pathways and identified strategies for improved collaboration across multiple agencies and stakeholders.

Additional Information

Readings

GRIDCO and CDRI. (2024). Lessons from Odisha: Developing Power Sector Resilience to Extreme Weather Events in Coastal Areas. https://cdri.world/upload/pages/1804897762250303_202407180637power-sector-policy-brief%20(odisha).pdf

A4: Strengthening Non-Structural Resilience of Public Schools to Seismic Events, Portugal

Portugal

Submitted by:
National Authority for Emergency and Civil Protection, Government of Portugal

Introduction to the Initiative

Natural hazards like earthquakes, of varying intensity and magnitude, are frequent in Portugal. Earthquakes generate serious and prolonged socioeconomic effects which impact not only buildings but also the lives of the citizens. In other words, the impact of earthquakes both structural and non-structural in nature. Hence, in 2023 a project was commenced within the scope of the activities of the Portuguese National Platform for Disaster Risk Reduction, with a view to promote non-structural seismic reinforcement of public schools.

Detailed Description of the Initiative

Compared to other regions of the world, the Iberian peninsula shows moderate seismic activity, particularly the regions located in the south. This is due to the convergence of the Euro-Asian and African tectonic plates. The historic record of seismic events in Portuguese territory shows that the country has been affected by earthquakes of moderate to strong magnitude, especially in the regions of Algarve, the Alentejo coastline and Lisbon Metropolitan Area. It is further estimated that the failure of non-structural elements is the cause of almost 60 to 70 percent of injuries during an earthquake. Hence, it is important to promote a culture of safety, based on the planning and execution of preventive actions that can mitigate the adverse impacts of seismic events.

Under the scope of the activities of the Portuguese National Platform for Disaster Risk Reduction, a group of public and private entities, such as the Portuguese National Authority for Emergency and Civil Protection, the General Directorate for Schools, the General Directorate for Education, several Portuguese universities, security forces, the Lisbon City Council and the Professional Association of Engineers, decided to develop a project focused primarily on the non-structural seismic reinforcement of public schools located on the Portuguese mainland. In Portugal two schools were selected as focal points for risk communication: Rainha D. Leonor Secondary School and Padre António Vieira Secondary School. Both schools were built in the late 1950s and were recently rehabilitated and seismically reinforced.

The main objective of the initiative is to promote the adoption of non-structural seismic reinforcement measures at public schools. The initiative intends to:

- reduce the potential for injuries and casualties, and also economic losses;
- maintain building exits clear and safe for evacuation;
- reduce the potential for chemical spills, fires and gas leaks;
- protect school equipment and educational materials;
- protect school information by having backups of vital information;
- increase the community's capacity to keep the public schools functioning post-disaster
- ensure that children can return to school, limiting educational interruption after an earthquake.

The following steps were taken to implement this initiative:

- Dissemination of information to schools on the non-structural actions that can be implemented with a view to mitigating seismic risk. For this purpose, a set of guidelines was produced, with recommendations to be implemented with a view to reinforcing the non-structural seismic safety of school establishments. This document was distributed to all public schools.

- Face-to-face interaction in schools was conducted with an aim of raising awareness among teaching and non-teaching staff about the importance of implementing non-structural measures to mitigate seismic risk. Seven public schools located in Algarve and the Lisbon Metropolitan Area were visited. After the visits, a report for each school was prepared, identifying non-structural insufficiencies and suggesting corrective measures. After a brief period, a second visit was conducted in two of the seven public schools that implemented the necessary corrective measures.

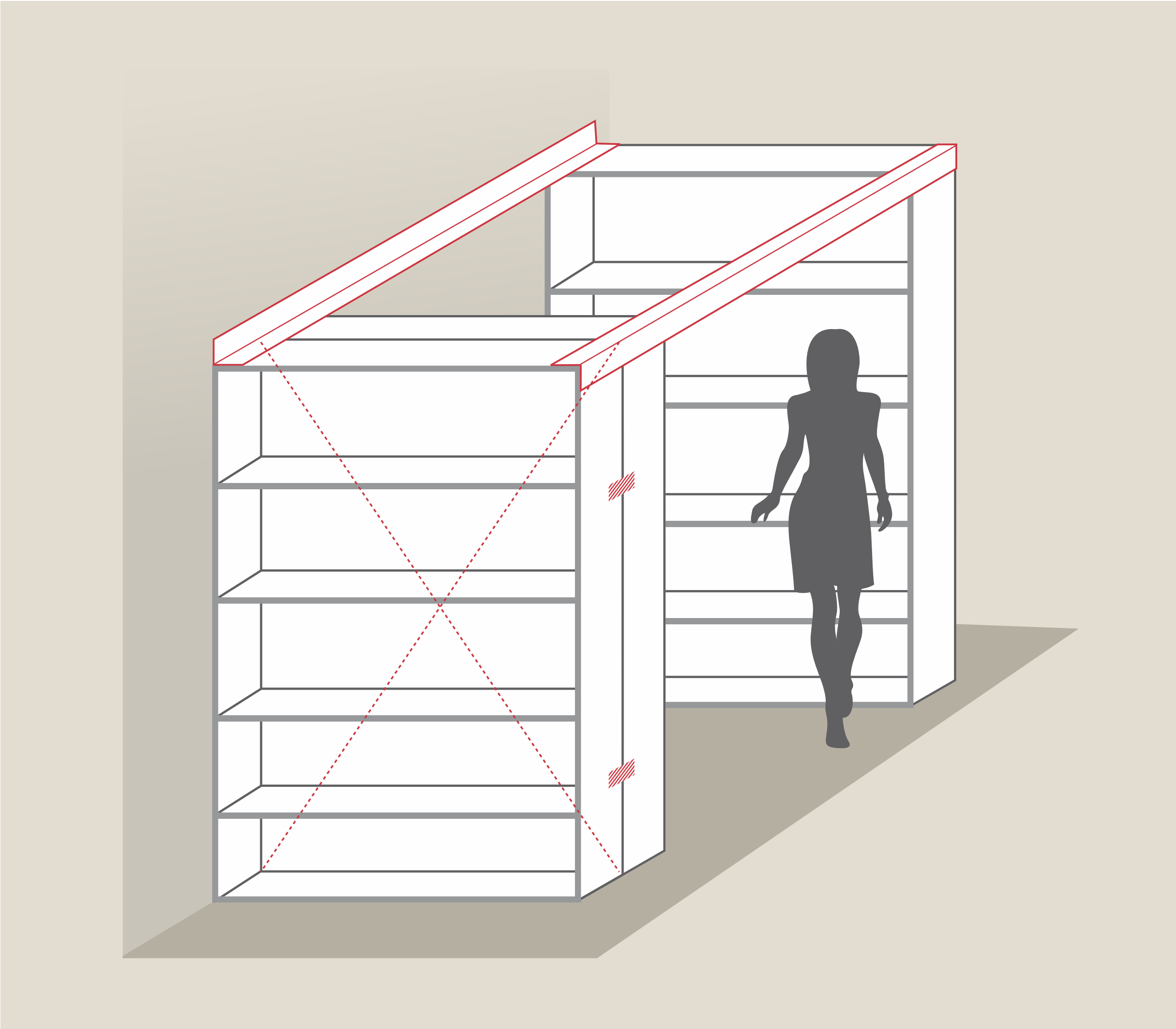
- Added-value demonstration was also conducted and a webinar was organized, aimed at the entire national public-school community. The aim of this webinar was to illustrate and raise awareness about the corrective measures undertaken in the two focus schools that implemented the necessary non-structural measures to mitigate seismic risk.

This project intends to demonstrate that apart from structural measures, resilience can also be achieved through low-investment initiatives, which have the potential to generate large-scale results and have a direct impact on the safety of target groups involved. Such initiatives can be especially relevant to communities with lower financial resources and contribute to Target D of the Sendai Framework for Disaster Risk Reduction, which calls to "substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them educational facilities, including through developing their resilience".

Learnings and Impact

This project is ongoing and has been currently implemented on a pilot scale. Despite low investment, the project faced some initial resistance which was overcome by showcasing the strong commitment towards resilience building and the success of the engagement with the entire school community including students, teachers and staff during the pilot stage.

Under the domain of the Portuguese National Platform for Disaster Risk Reduction, all project partners are now pushing to scale the initiative, by disseminating and implementing non-structural measures in more Portuguese public schools, including some private schools as well. Project partners also intend to scale this initiative to other sectors like health.



An example of a non-structural measure in a school library

Additional Information

Video Link

DGEstE Ministério da Educação, Ciência e Inovação. (2023). Webinar Sismos Prevenção e Ação nas Escolas. YouTube. https://www.youtube.com/watch?v=Dmitm11iwrA

Readings

Seismic Resilience Circular. (2023). Circular-interna-Resiliencia-Sismica_VFinal.pdf (pnrrc.pt)

Project Website: https://knowriskproject.com/?lang=pt

A5: Construction of Alluvial Control Works in Quebrada Bonilla, Chile

Chile

Submitted by:
Development Bank of Latin America and the Caribbean (CAF)

Introduction to the Initiative

The city of Antofagasta in northern Chile is located on a narrow coastal plain to the west of the coastal mountain range, which reaches an average height of 1,800 meters above sea level and covers a length of up to 80 km. This unique geography results in an abrupt relief, which is imposed by the coastal mountain range with several ravines flowing into it. Alluvial control work is being executed here as a part of the AdaptaClima project, which is an initiative of the Ministry of Environment and is being funded by the Adaptation Fund. The fund is implemented by the Development Bank of Latin America and the Caribbean (CAF) and executed by the United Nations Development Programme (UNDP). The project will help protect almost 100,000 inhabitants from alluvial floods, making the city more resilient. The project is amalgamating the climate change variables in its hydraulic analysis for updating existing engineering designs, and is a step towards embedding climate risks into project design. The project has a budget of US$2 million and will be executed in a duration of 210 days.

Detailed Description of the Initiative

In 1991, the city of Antofagasta was affected by an alluvial flood that caused damage throughout the city, and hence the need to seek better engineering solutions to control the water flow grew stronger. There was a need to control the water flow near the headwaters of the basins, or weaken it by diverting it to larger open areas where the water could spread without causing any damage or casualties.

To undertake this initiative, the Hydraulic Works Directorate of the Ministry of Public Works invited a call for proposals to suggest an engineering design for strengthening these water streams. Since 1993, the construction of alluvial control works has been carried out on 10 streams. The work included cleaning, protection of channels, channel rectification, construction of containment barriers, and rock or concrete dissipators and deflectors. This project was situated in the peripheral zones of the municipality and covered streams that flow into the city and experience alluvial flows. In 1998, work continued through the construction of a series of impermeable transverse barriers that could store a large part of the solids carried away by the alluvium.

The project covers the construction of the first stage of the 11th alluvial control work, located in Quebrada Bonilla. For this purpose, the existing initial design created in 2000 was updated, incorporating the current conditions of the topography and soils of the ravine and novel geotechnical, structural and hydraulic designs. The design criteria considered the future climate scenarios, using the climate projection for the most unfavourable scenario, RCP8.5 (Representative Concentration Trajectory in W/m2, which is a theoretical projection of a greenhouse gas concentration trajectory adopted by the IPCC), for a return period of 100 years.

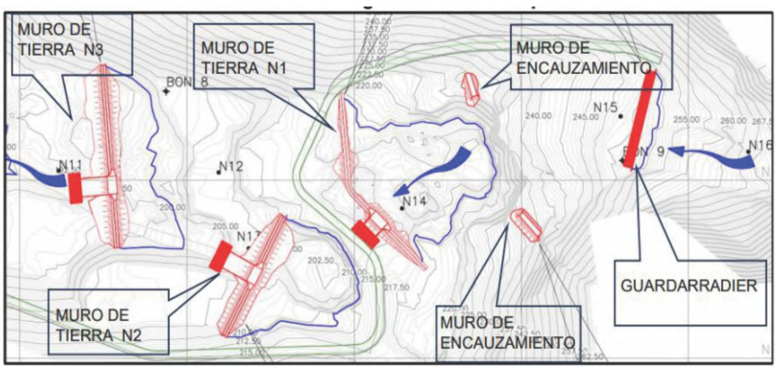
The project is set to further reduce the vulnerability of the population living in the vicinity of the Bonilla Creek, where there is considerable geological risk. A reduction in the flow velocity and the concentration of solid matter in the detrital current will reduce the impact downstream. In addition, the channels and dissipators will allow the runoff to be discharged in a controlled manner into the alluvial path, thus reducing risk to the existing infrastructure downstream.

Learnings and Impact

One of the main lessons learnt was the process of assimilation of the climate variables in infrastructure planning and design. The challenge was to incorporate future climate projections of the study area into the design, for which additional experts who were climate change specialists were invited into the design team. These experts selected the models that best suited the study area and helped incorporate climate projections into the design.

Chile is one of the frontrunners in incorporating climate change scenarios into various projects and has prepared many national-level adaptation strategies and action plans to combat climate change. Chile has also supported many research studies to understand the potential impacts of climate change in the country and possible ways of mitigation and adaptation. However, despite substantial progress made to date, there are still no official recommendations to incorporate climate projections into infrastructure project design. UNDP has initiated a project aimed at developing such guidelines that are aligned with international recommendations and scientific and technological advances in the field, although the scarcity of physiological and hydrometeorological information remains a challenge.

A document outlining methodological recommendations for incorporating climate change variables in the design of hydraulic works is being prepared for the northern zone of Chile. Upon completion, it will provide methodological recommendations for the northern zone of Chile (17°S – 32°15'S), which includes the regions of Arica and Parinacota, Tarapacá, Antofagasta, Atacama, and Coquimbo. This document will be endorsed by the Chilean Ministry of Public Works and it will act as a guideline for consultants, who will be able to incorporate these recommendations in their designs.



Satellite Imagery of Alluvial Plains

Additional Information

Video Link

PNUD Ecuador. (2023). Actualización de diseño de obras de control aluvional Quebrada Bonilla. YouTube.

A6: Revitalizing a Traditional Stone Masonry Dam for Flood Protection in Gudbrandsdalen, Norway

Norway

Submitted by:
Norwegian Geotechnical Institute, Government of Norway

Introduction to the Initiative

Small and steep catchments in Gudbrandsdalen Valley, Norway, respond rapidly to precipitation. In recent years, transportation and residential infrastructure have experienced repeated flood damage. To reduce the impacts of flooding and sediment transport, the European Horizon 2020 PHUSICOS project, coordinated by the Norwegian Geotechnical Institute, co-financed a nature-based solution at Skurdalsåa. The local landowners provided in-kind efforts, while Innlandet County and Sør-Fron Municipality were collaborative partners. Revitalizing the traditional stone masonry dam and selectively clearing vegetation along the tributary river proved successful during an extreme weather event in 2023, with no damage registered. This highlights the effectiveness of smaller interventions in enhancing disaster resilience of infrastructure.

Detailed Description of the Initiative

The Skurdalsåa River is one of the many steep tributaries to the main river Gudbrandsdalslågen, which flows through Gudbrandsdalen Valley in eastern Norway. Due to its relatively small catchment, Skurdalsåa experiences rapid increases in water levels after precipitation and snowmelt. Roads, houses, a school, a kindergarten, and a sports facility are all situated adjacent to the lower part of this river, and these assets have experienced repeated flood damage in the recent years. The river course has several bottlenecks due to its existing infrastructure, as well as culverts and bridges that are not built to withstand floods. Trees and other debris blocking the river at these bottlenecks have caused significant damage during the past flood events, leading to capital losses and high repair and recovery costs.

One of the interventions to make the surrounding infrastructure flood resilient, was the revitalization of a 19th-century stone masonry dam, utilizing the principles of nature-based solutions. This intervention was co-funded by the European Horizon 2020 PHUSICOS project, coordinated by the Norwegian Geotechnical Institute, with Innlandet County and Sør-Fron Municipality as the collaborative partners. The ownership of the above-mentioned lake and the dam, along with its irrigation rights, is shared between six local farmers. They formed a dam co-operative and registered it as a business entity in the Norwegian business registry. This enabled the implementing agencies to contract them the repair works by using their own machinery.

The physical work on the Lake Svintjønna Dam and spillway began in the autumn of 2022 and was completed by the end of the year. This period was chosen for construction because the irrigation of farmland was not necessary during that time. The modifications included a modest increase in the dam height by 0.5 meters, construction of a new discharge gate and threshold, and the installation of an automatic lake level monitor. The spillway was also improved and extended. An updated hydrological analysis has estimated that due to this intervention, a 200-year peak flood event can now be retained for up to two days, provided that the lake is initially tapped to its lower level.

In early summer of 2023, the local farmers carried out selective clearing of vegetation along the tributary. The forest was cleared to remove trees that were either in the river channel or in danger of falling over during a flood, which could cause problems such as sealing bridges and culverts during high flows.

These efforts were subsequently tested during the extreme weather event Hans that hit Norway in August 2023, causing devastating floods. Early forecasts made it possible to tap the dam before the storm struck, allowing the water to be released in a controlled manner and thus reducing water flow in the river. No damage was reported after the extreme weather event Hans, as per the news story published by the Innlandet County Council. This was a significant improvement from the major flooding events that happened in 2011 and 2013, during which the area along Skurdalsåa experienced severe flooding. The Innlandet County Council's website states that the estimated damage from those previous events was set at US$700,000 to US$900,000, excluding the damage covered by private insurance or damages to public infrastructure.

The old stone masonry dam from 1870 at Lake Svintjønna before revitalization

The old stone masonry dam after modifications completed

Learnings and Impact

Challenges that arose during the planning of this intervention were mostly related to receiving approval from the authorities regarding the modified dam height, as well as facilitating collaboration between the six landowners. It was crucial that the dam, after modification, was classified in dam class zero, which took a long time to get approved and clarified. Furthermore, all six landowners had to agree on the implementation of these modifications, despite having slightly different interests.

Although there were challenges, several factors contributed to the successful implementation of the measure. Funding through the EU project PHUSICOS was crucial. Additionally, the positive and active support from the municipality and the county council was important.

Throughout the Gudbrandsdalen Valley, many old irrigation systems and dams connected to lakes and ponds were established by farmers in the 18th and 19th centuries. An initial assessment indicates that there are 50 potential dams in this area alone. Many rural mountain areas in Norway, as well as across the Europe and globally, share similar characteristics, suggesting significant potential for upscaling. This revitalization highlights the effectiveness of relatively modest interventions that preserve as many natural settings as possible.

Additional Information

Readings

PHUSICOS Project Website. www.phusicos.eu

PHUSICOS. (2023). Nature-based solutions implemented in PHUSICOS. deliverable-d2-4.pdf (phusicos.eu)

A7: Updating Antofagasta's Stormwater Management Plan, Chile

Chile

Submitted by:
Development Bank of Latin America and the Caribbean (CAF)

Introduction to the Initiative

Antofagasta City's Rainwater Drainage and Evacuation Master Plan was updated under the AdaptaClima Project, which is an initiative of the Ministry of the Environment. The project is financed by the Development Bank of Latin America and the Caribbean's (CAF) Implemented Adaptation Fund and it is executed by UNDP. This activity was carried out in close coordination with the Ministry of Public Works of Chile. For this masterplan, updated information for Antofagasta regarding physical parameters and urban development, including climate projections for the years 2035 and 2065, was incorporated into the analysis. Information gathered from the recent hazard events such as the one that occurred in the northern part of the country was also taken into consideration. This novel approach for creating the masterplan was to make the city of Antofagasta resilient to floods.

Detailed Description of the Initiative

To update the plan, new information for the city of Antofagasta was collected for hydraulic modelling, through which the urban rainwater drainage was simulated for extreme events. The hydrological data from the extreme events for the 1979–2020 period was collected from historical records. The climate change projections for the 2035–2065 period as obtained from Global Circulation Models (GCM) were also applied to simulate the future scenarios. The simulations were utilized to express the future needs of the rainwater drainage system for the city of Antofagasta, specifically its network of primary collector drains.

The results showed that there would be an increase in the average intensity of precipitation events by 60 percent, and the events with longer return periods were to undergo the most marked changes. Apart from an increase in intensity of precipitation, the number of rainy days was projected to decrease in the future, which points towards more intense precipitation over a fewer number of days. Based on these results, climate variability was included in the hydrological design of the rainwater drainage system by utilizing stochastic approaches to make multiple climate projections and understanding the type of extreme precipitation events that might take place in the future.

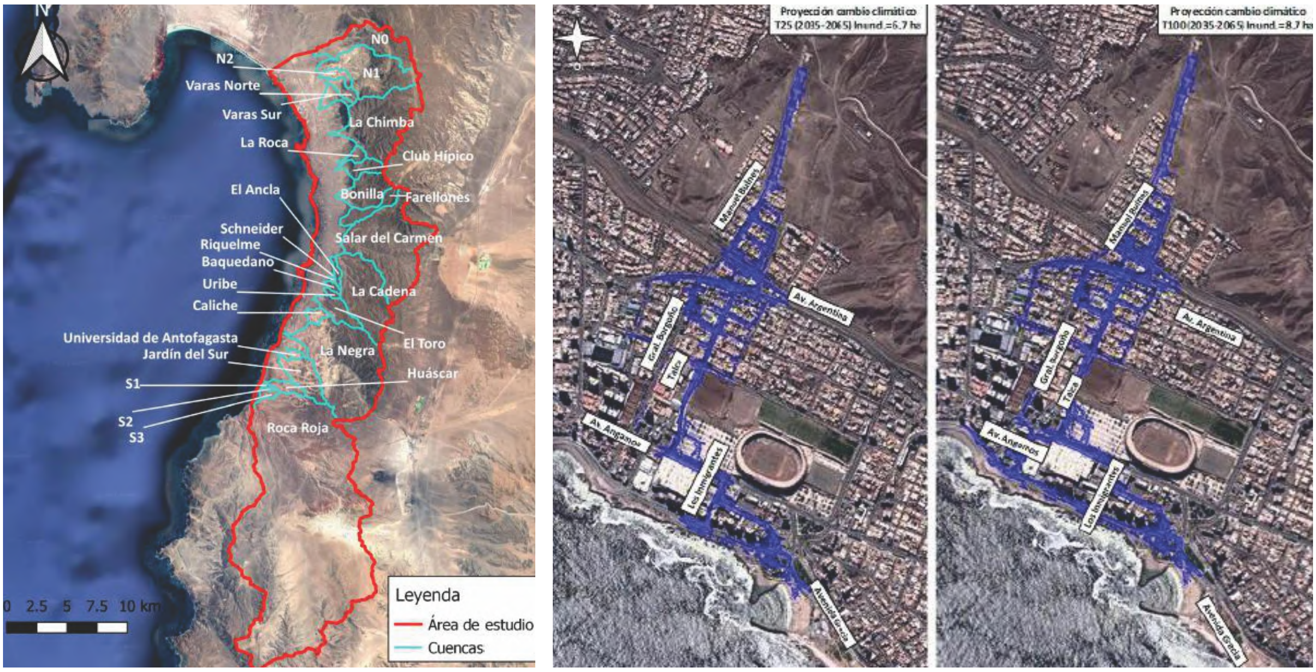
The population dimension, specifically regarding climate risks to residents, was also taken into account. There were two conclusions from this analysis. The first was that most settlements were in the category of "very low or none" or "low" degrees of exposure, and only five percent of the population was categorized as having "medium to high" degree of exposure. The medium to high degree of exposure was seen in settlements situated right next to streams.

The last step was the analysis of the present rainwater drainage situation in the city. It was found that areas with rainwater drainage problems were situated on a lower elevation and are concentrated on the streets perpendicular to the main run-off direction, i.e., from east to west. These settlements had certain physical elements that restricted the free flow of water, causing a decrease in the slope along the run-off axis. The impact of climate change on the city's drainage system was vastly different for flood events simulated for a return period of 25, 50, and 100 years. This difference was mostly seen in the coastal areas and not so much on the main run-off routes. As the city of Antofagasta has a unique topography with steep slopes, the impact on flooding of an increase in precipitation due to climate change was not much.

Learnings and Impact

The major challenge was that Antofagasta is a large city, and the budgetary constraints of the government meant prioritizing the needs for implementation. Many other challenges, like the availability of historical data, were overcome by working jointly with local institutions that had the information. Inter-institutional coordination also helped to update the plan efficiently. Working with the communities also strengthened the planning exercise, and they were involved in the process from beginning to end.

The benefits of the updated masterplan were seen in the city government understanding the location of the most vulnerable communities. The plan greatly helped the city to recognize high-risk settlements which were not recognized earlier and relocate them. The approach of accommodating climate models, future scenarios, and simulations during the planning process and especially in hydrological analysis is applicable to other plans as well and could be scaled at the national level. Although inter-institutional and stakeholder collaboration is essential to replicate Antofagasta's success, creation of knowledge and experience-sharing networks can facilitate scaling up of this initiative.



Drainage channels in Antofagasta

Additional Information

Readings

AdaptaClima Project Website. https://adaptaclima.org/download/actualizacion-del-plan-maestro-de-aguas-lluvias-antofagasta/

A8: Embedding Resilience in Metro Rail Systems: Case Studies of Delhi and Chennai Metro, India

India

Submitted by:
National Disaster Management Authority, Government of India

Introduction to the Initiative

Metro transit systems are one of the key interventions in Indian cities aimed at improving the quality and accessibility of public transport. By the year 2022, 18 cities in India had operational metro corridors, with the Delhi–NCR region having the longest and most extensive network, with an operational length of 392.44 km comprising 288 stations[5] and an average daily passenger load of more than 6 million riders as of March 2024. Apart from the Delhi–NCR region, Chennai Metro ranked third in total network length, amounting to 54 km with an average daily passenger load of more than 297,000 riders. Since 2014, the total funds released by the government of India towards the capital cost of these two projects amounted to more than INR 35,000 crores (approx. US$4.16 billion), which is an enormous investment.

While both the Delhi–NCR region and Chennai are highly vulnerable to urban flooding, Delhi is also vulnerable to earthquakes, and Chennai to tropical cyclones. To safeguard capital investments against the above-mentioned hazards, both metro systems have mainstreamed infrastructure resilience through various interventions. While Delhi Metro thoroughly embedded infrastructure resilience in design, planning, operations and maintenance stages, Chennai Metro conducted a detailed Climate Risk and Vulnerability Assessment (CRVA), which continues to inform decision-making towards a disaster-resilient Chennai metro system.

Detailed Description of the Initiative

Delhi

Delhi Metro Rail Corporation (DMRC) constructs and operates all the underground and overground routes of the Delhi metro network. DMRC's careful interventions to mainstream disaster resilience strategies during the construction and operations of the Delhi metro have enabled it to provide continuous service during and after disasters, with limited loss of operational hours. Given that Delhi–NCR is in Seismic Zone IV of India, it is crucial to make metro operations resilient to recurring earthquakes.[6] Further, some parts of Delhi–NCR are in the Yamuna floodplains, leading to flood risk. Delhi Metro is known for its punctuality, such hazards have led to delayed and slower services, as well as precautionary suspension of operations due to dust storms and earthquakes. The need to cater to the transport needs of the growing urban population of Delhi–NCR and commuters through underground and elevated routes requires a metro system resilient to earthquakes, floods and dust storms. DMRC identified this critical need from the planning stage itself. As a result, it regularly reviews and enhances operational resilience, both as a routine practice and as a response to improving operations post-disaster.

As part of its disaster resilience efforts, DMRC has taken the following measures:

- The Delhi Metro System has been designed to be resilient to earthquakes measuring 7 on the Richter scale,[7] in accordance with Indian codes.[8]

[5] Delhi Metro Rail Corporation Limited. (2024). Introduction. Available from: https://delhimetrorail.com/pages/fr/introduction

[6] Delhi Metro Rail Corporation Limited. (2020). Revised EIA for Priority Corridors of Delhi Metro Phase IV. https://backend.delhimetrorail.com/documents/54/EIA-Phase-IV-Priority-Corridors-August-2020-English-02012021.pdf

[7] Delhi Metro Rail Corporation Limited. (n.d.). Delhi metro: the safest place in Delhi during earthquake. Available from: https://www.delhimetrorail.com/otherdocuments/EARTHQUAKEguidelines.pdf

- Seismic sensing nodes have been installed as part of the Earthquake Warning System[9] in the Delhi Metro network. The warning system was designed by the Council for Scientific and Industrial Research.
- Emergency evacuation plans and guidelines have been issued for passengers, promoting public awareness on how to respond to earthquakes.[10]
- As part of the "Revised Environmental Impact Assessment" (EIA) in 2020, the DMRC ensured that planned bridges were designed to enhance the Metro System's resilience to floods during the design phase. Under the Disaster Management component of this EIA, DMRC has strengthened preventive action efforts, reporting procedures for safety measures, communication system, and response systems by constituting an Emergency Action Committee for better coordination. Other measures include the installation of emergency lighting and fire protection systems.
- Disaster preparedness actions for stations include earthquake preparedness exercises,[11] removal of floodwater at stations, improved exit routes, and securing elevated lines.
- At peak times during disasters, measures have been taken in accordance with the Disaster Management Act 2005.

  The DMRC has installed a Supervisory Control and Data Acquisition (SCADA) system, which tracks and monitors all interruptions, including voltage fluctuations lasting only seconds that cause momentary disruptions.[12]

As a result, the DMRC has successfully stopped services within minutes of earthquakes. Furthermore, during the flooding in July 2023, Delhi Metro services were able to operate during peak hours. Lower speeds were implemented as a precautionary measure. Hence, Delhi Metro was referred to as the "lifeline" of Delhi during the floods, with more than 99 percent punctuality and reliability. Nevertheless, during the aforementioned flooding event, the Yamuna Bank station was shut down due to flooding near its entry and exit gates, and a communication from DMRC was issued on social media stating that the station was inaccessible for some time, advising travellers to reroute their commute plans.

For dust storms, the DMRC continues its efforts to minimize damage to its equipment and ensure continuity of metro services. A major impact of dust storms is on power cables, which can affect continuous electricity supply. Therefore, strategies and design considerations were implemented to prevent damage from windstorms. In June 2018, when a dust storm with wind speeds of 70 km/h hit Delhi Metro, no major impact on services was reported, except minor regulation of trains on affected stretches.

Chennai

Metro operations in Chennai are managed by Chennai Metro Rail Limited (CMRL). The Chennai Metro system has been built as an alternative to road transportation in two phases. As of 2022, Phase I (54 km in length) and Phase II (more than 100 km in length), comprising five corridors with both underground and elevated tracks, were commissioned. Given rising temperatures, excessive rainfall, cyclones, and flooding, a need was identified in 2022 for climate change adaptation to mitigate the effects of such hazards on the Chennai Metro assets. The Tamil Nadu government took support from Asian Development Bank (ADB) in the form of the Chennai Metro Investment Project worth US$780 million, in tranches, to finance Corridors 3–5.

The CRVA for the Chennai Metro Investment Project enabled an understanding of the following:

- Cyclone hazard zones in Tamil Nadu, including areas in and around Chennai
- Hazard exposure such as simulated flood inundation depths

[9] CSIR: Central Scientific Instruments Organisation (n.d.). Earthquake Warning System for Metro Rail. Available from: https://www.csio.res.in/upload/PDF/earthquakewarning.pdf

[10] Delhi Metro Rail Corporation Limited. (2024). Emergency Evacuation Plan. Available from: https://www.delhimetrorail.com/emergency-evacuation-plan

[11] Pinkerton. (2014). Earthquake Disaster Preparedness Exercise in Delhi, the first of its kind in India. Delhi Disaster Management Authority. Available from: https://ddma.delhi.gov.in/sites/default/files/ddma/universal/updated_ddma-report_opt_1_2.pdf

[12] PEER. (2019). Delhi Metro Rail Corporation Limited (DMRCL) – Blue Line 3 and 4 Case Study. Available from: https://peer.gbci.org/sites/default/files/DMRC%20-%20CS%20Final.pdf

- Observed and projected trends of climate variation in Chennai, including temperature and rainfall
- The effects of rising temperatures on rail infrastructure, such as deformation and misalignment
- Stability and erosion
- Costs for climate change adaptation strategies, including flood gates for underground stations to guard against sea level rise and flooding from the Adyar River.

In the case of Chennai Metro, identification of risks and the long-term strategy for resilience and sustainability of the metro infrastructure have proven valuable to date. For example, when Cyclone Michaung struck in 2023, metro passengers in Chennai faced difficulties reaching metro stations due to waterlogged roads and flooded parking lots. Learning from this experience and the CRVA, the Chennai Metro Rail Limited (CMRL) has been able to implement the following measures:

- Inform maintenance and governance of operational metro corridors 1 and 2 from Phase 1.
- Assist in integrating disaster resilience into the planning and implementation of operations for Phase 2 (Corridors 3, 4 and Balance C5)[13] of the metro system. This includes the elevation of the alignment of the corridor to adapt to flooding risks, a greater number of pits for rainwater harvesting, increased drainage, and further installation of flood gates.
- Implementing rainwater harvesting system that collects and channels runoff, protecting assets around metro stations and viaducts, thereby reducing the chances of flooding in these areas.[14]
- Notably, this step reflects a commitment to systemic resilience, beyond the duties of CMRL. It recognizes the growing importance of mainstreaming disaster resilience for other hazards affecting the Chennai Metro, such as earthquakes (Chennai lies in Seismic Zone 3, moderate risk). Seismic designs have been integrated for Corridor Balance C5, and an evacuation plan has been introduced for Chennai Metro services.

Learnings and Impact

The process of mainstreaming disaster resilience of infrastructure in the metro systems of Delhi and Chennai has provided many lessons to engineers and policymakers. They include:

- Moving a step forward from existing standards and codes was seen as an important step in embedding resilience. This was crucial, specifically in the case of Delhi Metro, where the seismic codes for bridges were outdated and irrelevant. This issue was mitigated by a vulnerability assessment and risk analysis through which the seismic risk was addressed.
- Risk-informed planning by conducting CRVAs was beneficial for Chennai Metro's further construction initiatives. For example, the identification and costing of climate change adaptation measures, such as the installation of flood gates at underground stations, as conducted in the Asian Development Bank's CRVA in 2022 for Phase 2 (Corridors 3 and 4), proved to be a reference point for the Chennai Metro Rail Limited (CMRL) in 2024.
- Training and capacity building of engineering professionals was needed to implement these new structural interventions. A strong partnership with the project's Japanese counterparts from the beginning resulted in a culture of professionalism in the DMRC, and engineers were trained in new technologies to address this challenge.

[13] ADB. (2024). Updated Environmental Impact Assessment, India: Chennai Metro Rail Investment Project Balance Corridor 5. Available at: https://chennaimetrorail.org/wp-content/uploads/2024/04/Updated-Environmental-Impact-Assessment-Report-for-CMRL-Phase-II-Balance-Corridor-5.pdf

[14] CMRL. (2024). Environment. Issue 4. Available at: https://ta.chennaimetrorail.org/wp-content/uploads/2024/07/Environment-Newsletter-Issue-04.pdf

- Challenges were transformed into opportunities through project design, institutional setup, and stakeholder engagement.[15] To conduct certain tasks, such as excavation of the ground and shifting of water pipes, DMRC carried out these tasks itself after experiencing a few delays.
- Delhi Metro helped shape and scale the construction of metro rail projects across the country as part of the Indian Metro Rail Organizations' Society (I-Metro), which promotes a forum for knowledge exchange, setting best practices and benchmarks, innovation in urban transportation, capacity development, and international cooperation with research institutions and other metro organizations.

Additional Information

Readings

Delhi Metro Rail Corporation Limited. (n.d.). Delhi metro: the safest place in Delhi during earthquake. https://www.delhimetrorail.com/otherdocuments/EARTHQUAKEguidelines.pdf

CSIR: Central Scientific Instruments Organisation (n.d.). Earthquake Warning System for Metro Rail. https://www.csio.res.in/upload/PDF/earthquakewarning.pdf

Delhi Metro Rail Corporation Limited. (2024). Introduction. https://delhimetrorail.com/pages/fr/introduction

World Bank Group. (2017). The Delhi Metro: Effective Project Management in the Indian Public Sector. Global Delivery Initiative, Delivery Note. https://effectivecooperation.org/system/files/2021-06/jica_v6_0.pdf

[15] World Bank Group. (2017). The Delhi Metro: Effective Project Management in the Indian Public Sector. Global Delivery Initiative, Delivery Note. Available from: https://effectivecooperation.org/system/files/2021-06/jica_v6_0.pdf

A9: Rural Roads Improvement Project, Cambodia

Cambodia

Submitted by:
Asian Development Bank

Introduction to the Initiative

Approved in 2010, the Asian Development Bank's (ADB) first large-scale rural roads project in Cambodia took ambitious steps to build flood and drought resilience in the transport sector. This initiative was part of a pilot within ADB's Sustainable Transport Initiative. The project upgraded Cambodia's rural road network by paving more than 500 km of rural roads in seven provinces. The resilience solutions included elements focused on design, materials, eco-based approaches, capacity building, and emergency preparedness. In 2015, a second phase was approved followed by additional financing, expanding the scope by a further 1,200 km in 10 provinces. In 2018, a third phase was approved with further funding and coverage of 360 km in five provinces. The project will continue until 2026.

Detailed Description of the Initiative

Road transport is the principal mode of transport in Cambodia. As of 2010, the road network of about 39,400 km included about 4,800 km of national roads (primary national highways), 6,600 km of provincial roads (secondary national highways) and 28,000 km of rural roads. By the early 1990s, after several years of civil war, the country's road network had deteriorated greatly. As of 2010, development efforts brought the paved national and provincial road network to about 2,700 km in length, or about 23.7 percent of the total national and provincial road network. Meanwhile, the rural road network needed further improvement as it had deteriorated due to the steady growth in traffic, lack of maintenance, insufficient financing, poor implementation of road maintenance standards, inadequate contractor capacity, and design and construction deficiencies.

The project was designed to improve the rural road network in seven provinces in Cambodia mainly around the Tonle Sap basin. The expected project impact was to improve access to markets, jobs and social services in the seven provinces. The expected project outcome was safe, cost-effective, all-year road access provided in remote agricultural areas in the 7 provinces.

Learnings and Impact

The Asian Development Bank's Operational Priority 3 (Tackling Climate Change, Building Climate and Disaster Resilience and Enhancing Environmental Sustainability) sets out an approach to enhance the physical, eco-based, financial, social, and institutional resilience of Developing Member Countries. ADB projects seek to build resilience in one or multiple following areas. The present project adhered to these broader guiding principles.

- **Physical Resilience:** Assessment and mapping of climate vulnerability, including extreme weather, was undertaken to identify risks, inform hazard maps, and prioritize resilience solutions. Seasonal flood risk was addressed by upgrading and strengthening paving and constructing water retention ponds.

- **Eco-Based Resilience:** The project delivered green road corridors to build flood and drought resilience by increasing green cover, flood water infiltration, and water retention capacities. The project also implemented widespread planning of climate-adaptive trees and grasses.
- **Social and Institutional Resilience:** The project provided capacity building on climate and disaster-risk informed asset management and emergency management planning for rural roads to the Ministry of Rural Development. It piloted the use of climate monitoring systems to improve road management and maintenance, responding to challenges of increased seasonal variability.

The project included a community-based road maintenance program that trained 100,000 villagers on road safety awareness, established a provincial Emergency Operations Centre and three village flood shelters, and refurbished an Emergency Information Centre. Safety school zones were constructed, and 26,000 students were trained in road safety. The implementation of safety school zone helped reduce accidents near schools and promoted participation of teachers, students, and the local community in road safety. The project also trained women on road construction and maintenance and provided them equal access to jobs offered under the project, such as truck monitoring and road measurement and maintenance.

At completion of the first phase in 2016, the project achieved the following: (a) rehabilitated 545.3 km of rural roads in eight provinces; (b) reduced, by 50 percent, the violations of overloaded trucks in the project provinces, mainly by the installation of overload control gates; (c) improved the average roughness of project roads (from 6–14 to 2–3); (d) increased annual operation and maintenance budget for project roads from $275 per km to $320 per km; (e) facilitated potential accreditation by the Ministry of Rural Development of 10 small-scale road contractors; and (f) developed an emergency management system for rural roads, and constructed one Emergency Operations Centre and three shelters in the most vulnerable location in Kampong Thom Province to which all residents at risk can be evacuated within 72 hours after a typhoon occurs.

A10: Improving Climate Resilience at Airports: Kansai International Airport, Japan and Changi International Airport, Singapore

Japan and Singapore

Submitted by:
Royal HaskoningDHV

Introduction to the Initiative

This case study explains the objectives, methods and outcomes of two projects which were undertaken to bolster resilience of airports. The first project studied the impact of typhoons and other hazards on the functioning of the Kansai International Airport in Japan, and mapping of the potential risks from natural hazards such as sea level rise, erratic wind patterns and rainfall events, lightning strikes, extreme heat stress, reduced visibility and wildlife at Changi International Airport, Singapore.

Detailed Description of the Initiative

Kansai International Airport

The airport is built on reclaimed, low-lying land, making it susceptible to floods. In the aftermath of a 1-in-25-year typhoon event which brought the airport to a two-week standstill, the operators of Kansai Airport decided to bolster their natural disaster mitigation by increasing institutional capacity building and adapting for faster post-disaster recovery by combining grey-green infrastructure. The three key goals of the intervention were:

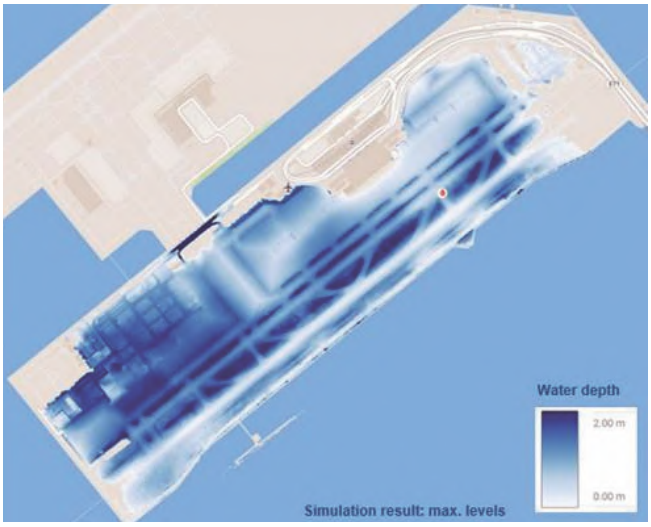
- Anticipate the effects of climate disasters on the airport infrastructure and other critical assets.
- Develop a detailed mitigation plan that will increase the protection of passengers and staff members, critical assets, and priority areas.
- Reduce the impact of climate disasters and decrease the downtime of operations by initiating cost-effective adaptation measures and minimizing delays.

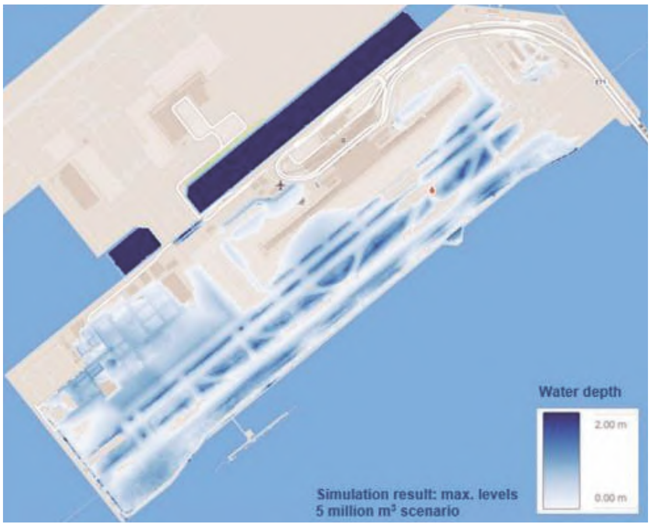
The project team brought together a unique combination of domain expertise in airport planning along with water and flood resilience to deliver an effective, cost-efficient, climate-resilient solution which could be implemented smoothly.

The Circle Tool was used alongside Royal HaskoningDHV's (RHDHV) Flood Simulation Tool, which was calibrated, in collaboration with Kansai Airport, to recreate the typhoon-induced flooding of 2018. This resulted in a precise simulation model that could explore the impacts of future climate event scenarios. The Circle Tool is a dynamic visual platform that maps all critical airport assets as segments that make up a circle – and shows inter-relatedness. Subsequently, the tool shows the cascading effect that a typhoon or a similar flood disaster has on these assets. For example, the tool shows that if the airport's substations that power the water pumps were affected, it would result not only in the runway being flooded but also the switchgear rooms in the basement of the terminal, which in turn would make the intercom system go down, affecting effective communication to passengers during the emergency.

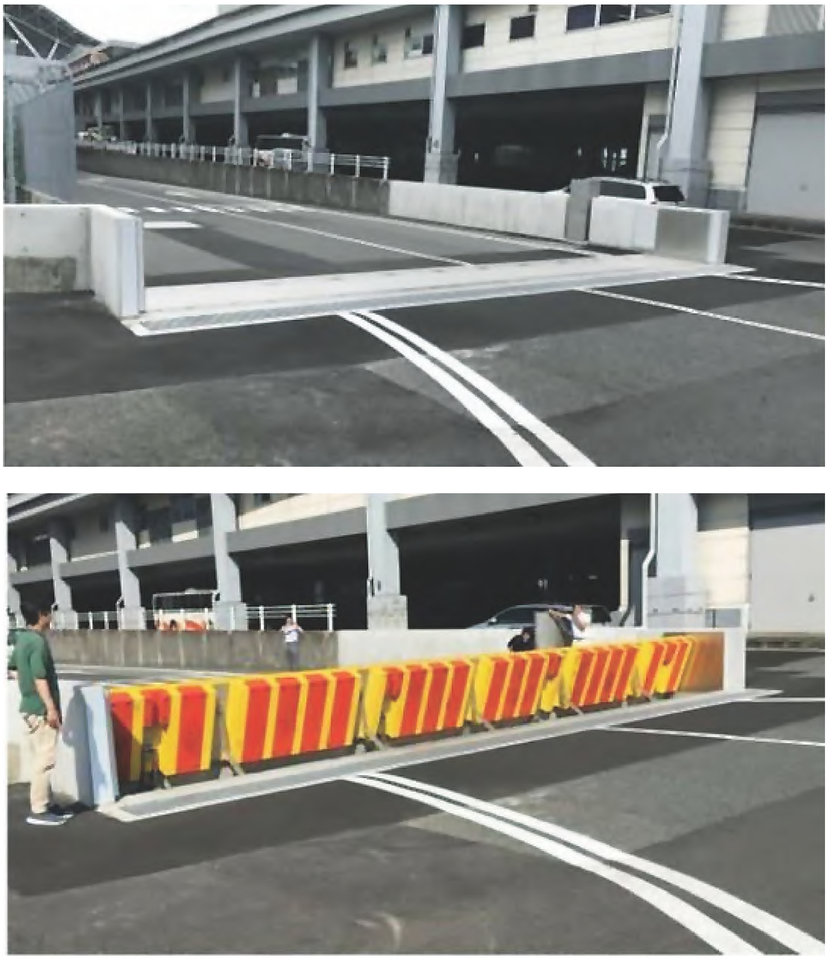
Based on the output from the Circle Tool and consensus on critical assets amongst stakeholders, multiple mitigation options were tested within the Flood Simulation framework to provide the most optimal protection of critical airport infrastructure. Subsequently, various mitigation measures were created and narrowed down based on the criteria of enhanced climate resilience and time and cost-efficiency. Investment estimates were created for two final solutions, both of which promised to reduce airport downtime from the two weeks experienced in 2018 to two days.

Disaster countermeasures being installed at Kansai International Airport after the typhoon on 4 September 2018





Images showing flood water depth at various scenarios



Flood counter-measures being implemented at Kansai International Airport
Source: Royal HaskoningDHV

The Circle tool, designed to showcase the cascading effect of utility failures at the airport
Source: Royal HaskoningDHV

Changi International Airport, Singapore

Changi Airport, one of the world's foremost transportation hubs, serves as a vital gateway to Asia and beyond. Considering escalating climate impacts, the airport authorities needed expert guidance to determine the potential risks to their airport infrastructure and operations, and recommendations on how to keep the airport operating smoothly as the climate changes. The project supported the airport with valuable insights into the risks and associated measures that can be implemented to adapt and increase its resilience. This included climate stressors and scenario analysis, assessment of climate risks on assets and operations, and the development of measures to build institutional capacity for a climate-resilient 2050.

First, the team carried out climate scenario modelling. They combined operational data with weather information received from Meteorological Service Singapore and the Centre for Climate Research Singapore to get a clear picture of potential operational problems the airport might face in the future due to climate change. Next, they engaged stakeholders in Changi Airport through workshops to map climate risks. Together with airport stakeholders, they mapped the potential impact of a disruptive event and drew connections on how a single disruption can impact multiple assets and operations. They used RHDHV's digital tool STAIN to visualize these cascading effects and highlight the interconnected nature of airport operations.

Following the identification of key risks, and again working closely with the airport's stakeholders, the team developed measures to reduce these risks and increase airport resilience, covering everything from infrastructure to procedures and guidelines. The project underscored the importance of cross-cutting expertise desirable to formulate a climate resilience plan for an airport. The strategic and collaborative approach empowered the stakeholders to take ownership of the decision-making processes, with identification of practical measures for the near and long-term.

Changi Airport
Source: Royal HaskoningDHV

Learnings and Impact

At Kansai International Airport, in-depth modelling and pertinent scientific expertise provided a clear vision on what assets were at risk, including the ways by which the risk could be mitigated or avoided, and the solutions and investment needed. Strong stakeholder involvement provided a detailed understanding of the airport assets in relation to climate resilience, helping the airport make improvements that will reduce downtime during future climate events. Some notable outcomes were:

- Reducing climate-related downtime from two weeks to two days
- Increased protection of critical assets and priority areas
- Safeguarding passengers and staff during extreme weather
- Boosting stakeholder collaboration and understanding of flood scenarios

At Changi Airport the result of this exercise was a clear Climate Adaptation Pathway, detailing how Changi Airport can become more resilient to climate change and potential risks in terms of sea level rise, erratic wind patterns and rainfall events, lightning strikes, extreme heat stress, reduced visibility, and wildlife. The pathway laid out what steps the airport can take today and what can be achieved by 2050. By implementing the recommendations in this plan, Changi Airport can continue to be a safe, efficient and world-class transportation hub and gateway to Asia for years to come. The collaborative approach, engaging with all stakeholders, increased the understanding of interrelations of different components and departments of the airport and fostered a stronger sense of collaboration within the airport community.

As a result, the Changi Airport Group (CAG) has introduced new measures to keep its airside workers cool and protected against the heat. As many as 30,000 workers work airside, in multiple roles such as ramp assistants, aircraft maintenance engineers and in-flight catering drivers. These heat stress management measures are but one part of managing higher ambient temperatures at Changi, under CAG's climate resilience strategy. Foresight and early planning are critical to fostering long-term climate resilience for Changi Airport to enable operational continuity for passengers. CAG now continually seeks to bolster Changi Airport's resilience to climate change through infrastructure adaptation measures.

The two initiatives have generated many co-benefits such as:

- ➔ **Improved Collaboration and Stakeholder Engagement:** The collaborative approach of engaging multidisciplinary stakeholders fostered a stronger sense of collaboration and ownership within the airport community. This improved collaboration enhanced communication, coordination, and understanding of interrelations among different components and departments of the airport, leading to more effective decision-making and problem-solving.
- ➔ **Enhanced Safety:** Reducing the risk of damage, disruption and potential harm during flooding events has improved flood resilience, the safety of passengers, staff, and infrastructure at the airport.
- ➔ **Business Continuity:** The project will help ensure the continuity of airport operations even in the face of disasters. By implementing measures such as backup power systems, relocatable equipment, and emergency response plans, Kansai International Airport will be able to maintain essential services, minimize downtime from two weeks to two days, and prevent significant financial losses during flood events.
- ➔ **Reputation and Stakeholder Confidence:** The project not only enhances an airport's reputation but also instils confidence among stakeholders, including airlines, passengers and investors. The airport will be seen as reliable and capable of managing emergencies, attracting business, and maintaining positive relationships with stakeholders.
- ➔ **Knowledge Sharing and Innovation:** The project involved knowledge sharing, collaboration, and innovation. Other airports can exchange best practices, learn from experiences of Kansai International Airport, and contribute to the development

of innovative flood mitigation strategies. This fosters continuous learning and drives advancements in airport flood resilience worldwide.

- **Employee Well-being:** The introduction of heat stress management measures for airside workers demonstrated Changi Airport's commitment to the well-being and safety of its staff. Prioritizing employee health and productivity will continue contributing to a positive work environment as more actions are implemented.
- **Long-term Operational Continuity:** Foresight and early planning for climate resilience has enabled Changi Airport to ensure long-term operational continuity. By proactively implementing infrastructural adaptations and climate resilience strategies, the airport will continue to function efficiently and serve passengers without significant disruptions caused by climate-related events.

Implementation Challenges and Mitigation Strategies

It was crucial to ensure that any potential solutions would need to safeguard both the continuity of airport operations and improve flood resilience. In approaching a solution, the project team sought to bring together stakeholders across various disciplines within the airport. By exploring the needs and requirements of each, they created a shared vision of what is necessary to serve the immediate needs of Kansai Airport today and the improvements required to safeguard it in the future. To enable and facilitate these conversations and collaborations, they employed the use of new digital platforms like the Circle Tool. The tool allowed them to communicate data and insights in a common visual language, thereby cutting through the complexity to enable informed decision-making for the client, including generating insights into where to invest mitigation efforts.

Scalability

All airports can accommodate a long-term perspective towards disaster resilience and can simultaneously work towards mitigation, adaptation and resilience objectives to ensure business continuity and contribute to a safe and comfortable passenger experience.

It is important to note that each airport's flood risk profile is influenced by factors such as geographic location, local climate conditions, and the effectiveness of flood prevention measures in place. Although the specific nature and magnitude of the risks may vary, the lessons learnt from this project can also be applied to other airports which are in low-lying areas and are prone to flooding, hurricanes and heavy rainfall events. Lessons are also applicable to airports located in a coastal area likely to be susceptible to storm surge and sea level rise.

The extensive adaptation roadmap enables Changi Airport to continue its climate resilience journey as Singapore's first-in-class aviation hub. It is important to continue with climate change response capacity and knowledge-building efforts. Furthermore, continual monitoring of climate risks and resilience measures as part of CAG's Enterprise Risk Management has been put in place and is planned to be enforced through a periodic reevaluation (every five years). This intervention offers important operational and strategic lessons for replication in similar settings, particularly in the context of formulating a climate resilience strategy which is focused on critical infrastructure.

- **Collaboration with government-led initiatives:** Coordinating efforts were led with district-wide measures to mitigate natural impacts as well as achieve overall sustainability of the project. This included building a strategy plan which could be implemented within the existing frameworks of green procurement, sustainable aviation fuel, and zero-carbon policies.
- **Uncertainty and future projections:** Dealing with uncertainties in climate projections and decision-making meant that any long-term planning and decision-making had to balance incremental changes with strategic investments.

B Embedding Resilience through Post-Disaster Reconstruction of Infrastructure

Theme B

B: Embedding Resilience through Post-Disaster Reconstruction of Infrastructure

Post-disaster reconstruction offers an opportunity to build back stronger, more resilient infrastructure capable of withstanding future hazards. This section highlights key lessons drawn from three case studies in Tonga, Nepal and Sweden in embedding resilience during the reconstruction of critical and social infrastructure after a disaster.

A common lesson that emerged from across the three case studies is the importance of having strategic frameworks in place before disaster strikes.

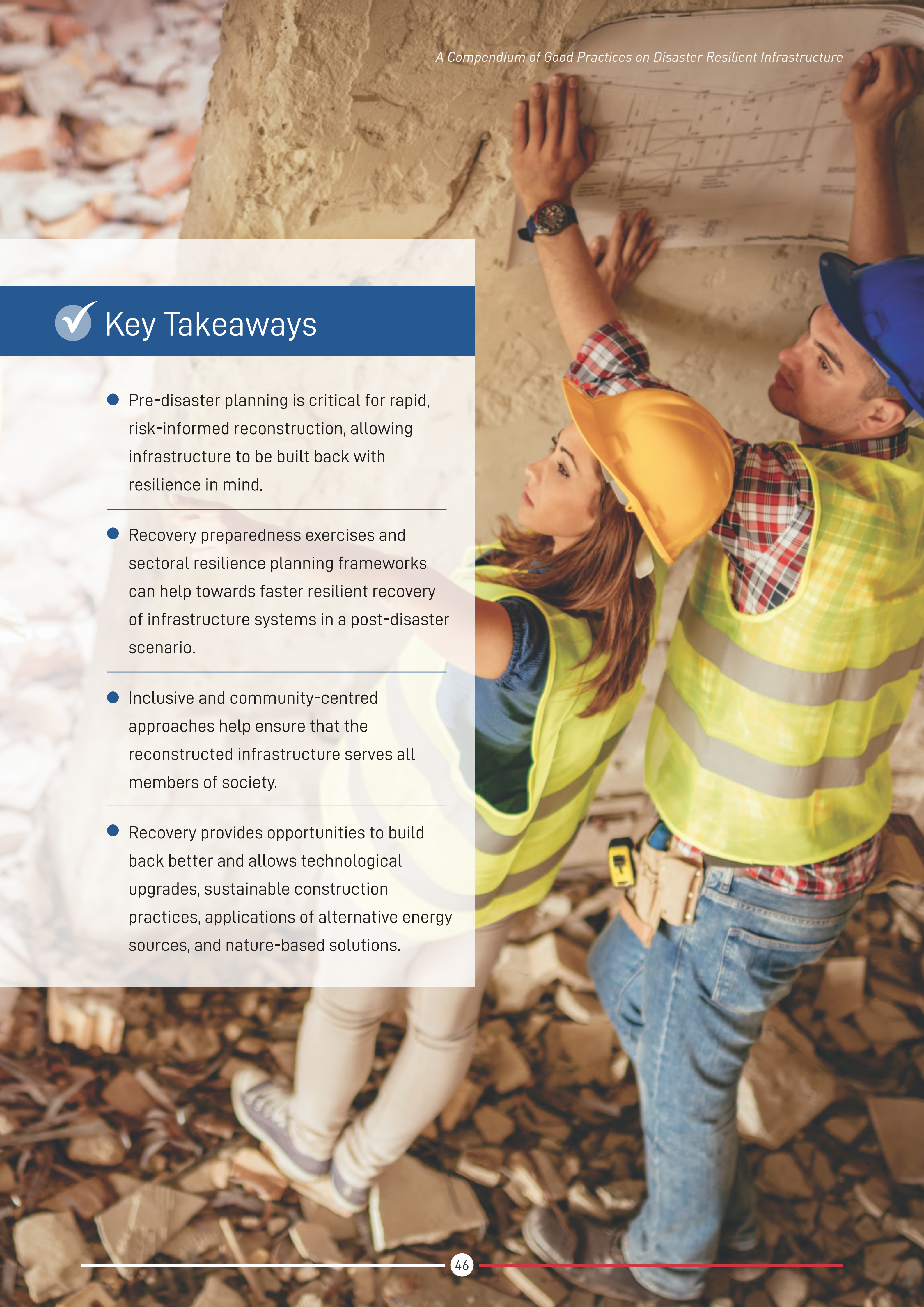
Tonga's recovery from Cyclone Gita included a 10-year Resilient Energy Roadmap, which guided the rebuilding of its power infrastructure. Similarly, the Ministry of Education's preexisting designs in Nepal were adapted to make school buildings more resilient to earthquakes. In Sweden, the retrofitting of the Slussen Lock was driven by comprehensive climate and hydrological modelling that forecast future flood risks. These cases demonstrate that pre-disaster planning is critical for rapid, informed reconstruction, allowing infrastructure to be built back with resilience in mind.

Decentralization and modern technological upgrades emerged as vital strategies in rebuilding infrastructure. In Tonga, decentralizing the power grid by moving connections underground and upgrading technical standards made the network more resilient to future storms. Similarly, in Nepal, schools were reconstructed with earthquake-resistant designs, incorporating steel structures and backup solar energy systems. In Sweden, the Slussen Lock was retrofitted to increase water discharge capacity fivefold, with foundations "oversized" to accommodate future flood gates in response to rising sea levels. These interventions show how post-disaster reconstruction can adopt decentralized, flexible and technologically advanced solutions to better manage future risks.

Inclusive and community-centred approaches were essential in ensuring that the reconstructed infrastructure serves all members of society. In Tonga, women made up 33 percent of the workforce involved in power grid reconstruction, reflecting a commitment to gender inclusivity. Nepal's school reconstruction efforts emphasized accessible design, incorporating gender-sensitive toilets and facilities for students with disabilities. In Sweden, the Slussen Lock project was designed to improve public transport, increase pedestrian and cycling traffic, and create green spaces for local communities. These examples demonstrate how inclusive design can improve both social equity and the long-term resilience of infrastructure by ensuring that it meets the needs of diverse populations.

Localized and nature-based solutions played a critical role in enhancing resilience. In Nepal, the safety of schools was ensured by using nature-based measures like planting vetiver grass to stabilize slopes and mitigate landslide risks. In Sweden, the Slussen Lock retrofit considered the unique hydrological challenges posed by Lake Mälaren's proximity to the Baltic Sea, incorporating responsive hydrological monitoring and water regulation plans. These case studies highlight the importance of tailoring reconstruction efforts to the specific environmental conditions of each location, using local knowledge and nature-based solutions to address long-term sustainability and disaster resilience.

Sustainability and capacity building were central to ensuring the long-term success of post-disaster reconstruction projects. In Tonga, integrating renewable energy solutions and improving underground power systems contributed to a more resilient energy supply. Nepal's schools incorporated solar power systems to reduce reliance on the grid, and Sweden's retrofitted Slussen Lock was designed to handle future climate change impacts for up to 100 years. In all three cases, local capacity was strengthened through training, ensuring that the rebuilt infrastructure could be maintained and managed effectively in the future.



Key Takeaways

- Pre-disaster planning is critical for rapid, risk-informed reconstruction, allowing infrastructure to be built back with resilience in mind.

- Recovery preparedness exercises and sectoral resilience planning frameworks can help towards faster resilient recovery of infrastructure systems in a post-disaster scenario.

- Inclusive and community-centred approaches help ensure that the reconstructed infrastructure serves all members of society.

- Recovery provides opportunities to build back better and allows technological upgrades, sustainable construction practices, applications of alternative energy sources, and nature-based solutions.

B1: Cyclone Gita Recovery Project, Tonga

Tonga

Submitted by:
Asian Development Bank

Introduction to the Initiative

Severe Tropical Cyclone Gita was the most intense storm to ever hit the Pacific Island nation of Tonga. Making landfall on 12 February 2018, it caused severe damage to the islands of Tongatapu and 'Eua. Widespread destruction of the power network disrupted communities and led to energy sector reconstruction costs of about $46 million. In 2018, the Asian Development Bank (ADB) and the government of New Zealand approved separate grants to help reconstruct and improve disaster resilience of the Nuku'alofa electricity network, in partnership with the Government of Tonga and Tonga Power Limited.

The power network recovery was informed by an existing 10-year Energy Roadmap and lessons in building back better from the Cyclone Ian Recovery Project in 2014. Some 5 percent of power grid segments upgraded in Tongatapu and 'Eua through earlier support were found to be damaged following Cyclone Gita, compared to a damage of about 45 percent in other areas. ADB is continuing its support for national energy resilience through the 2019 Tonga Renewable Energy Project.

Detailed Description of the Initiative

Tropical Cyclone Gita hit Tonga on 12 and 13 February 2018. It caused widespread destruction on Tongatapu, including Nuku'alofa, and the neighbouring island of Eua. With average wind speeds of 130 km per hour and gusts of up to 195 km per hour, it was the strongest cyclone to directly hit Tongatapu and 'Eua since severe Cyclone Isaac in March 1982.

An accompanying storm surge reached 1 metre above normal high-tide levels, and 200 mm of rain fell within 24 hours, resulting in localized flooding. It is estimated that more than 80,000 people (or about 80 percent of the population of Tonga) were directly affected. The destructive winds, storm surges, and flooding brought down power lines; damaged and destroyed schools; destroyed crops and fruit trees; and damaged public buildings, including the domestic airport, the Parliament building, and Tonga meteorological services. Nearly 5,000 houses were either destroyed or damaged. The government declared a state of emergency for the whole of Tonga on 12 February 2018. The Cyclone Gita Recovery project was expected to deliver impacts toward more reliable and safe energy services, reduced energy consumption, increased resilience to disasters, and safer and more reliable buildings and structures to improve services and maintenance. Its intended outcome was to restore reliable electricity supply in priority areas of Nuku'alofa. The project's target output was to rehabilitate and upgrade priority sections of the Nuku'alofa electricity network.

Maintenance activities of energy infrastructure in Tonga
Source: Asian Development Bank

Installation of electric conduits on building walls
Source: Asian Development Bank

Learnings and Impact

The Asian Development Bank's Operational Priority 3: Tackling Climate Change, Building Climate and Disaster Resilience, and Enhancing Environmental Sustainability, sets out an approach to enhance the physical, eco-based, financial, social, and institutional resilience of Developing Member Countries. ADB projects seek to build resilience in one or multiple areas.

The project enhanced the physical resilience of Tonga's power system by building a more decentralized network with strengthened distribution assets. Specific measures included moving service connections underground, changing distribution system aerial conductors from individual to bundled lines, upgrading the capacity of the distribution network, providing high voltage underground supply to critical locations such as hospitals, network reconfiguration to support rollout of renewable energy, and applying the latest technical standards from Australia and New Zealand.

The project also set high targets for capacity development and gender inclusion in order to develop a more diverse workforce that is better equipped to respond to future disasters. Capacity building included training and coaching for Tonga Power Limited to meet gender and social targets and strengthen implementation and coordination capacity for future emergencies. As a result of these gender diversity efforts, women now comprise 33 percent of TPL's line crew.

At project completion, 2,184 customers were connected to the network, with sufficient provision to cater to any new connection requests arising from new developments in the area. A total of 256 customers were also able to connect to the grid energy for the first time and 71 new three-phase power connections were provided. A total of 24 transformers and 35 km of high-voltage and 103 km of low voltage lines were used.

It is noted that 19 km more of the high-voltage and 45 km more of the low-voltage cables were used over the estimated lengths. This is attributed to the completion of the entire Area 2 upgrade work against a target of 90 percent at appraisal, and to the extension of cables to vacant locations earmarked for upcoming development. In addition, a total of 830 11-meter length poles for high voltage cabling and 2,214 9-meter length poles for low voltage cabling were installed. Overall, the project met its expected impact and outcome targets and exceeded the output targets within the original budget and implementation timeline.

B2: Post-earthquake School Reconstruction, Nepal

Nepal

Submitted by:
United Nations Office for Project Services (UNOPS)

Introduction to the Initiative

The 2015 earthquake in Nepal destroyed over 500,000 houses and partially damaged another 269,000. Among other sectors, education was severely affected, with over 9,000 school buildings being damaged and 7,553 destroyed. A total of 49,681 classrooms were damaged, with 21,169 completely collapsed, 12,522 severely damaged, and 15,990 partially damaged.

Consequently, access to education was further compromised for children of socially vulnerable groups in geographically isolated areas. Classes were being held outdoors or in overcrowded temporary learning centres. The lack of an appropriate school environment increased the risk of dropout and protection issues, and reconstruction of schools was urgently needed.

In December 2018, UNOPS and the Norwegian Embassy agreed to build 24 new earthquake-resilient school buildings with 144 classrooms, and gender-sensitive and disabled-friendly toilet blocks, in earthquake-affected remote districts.

Detailed Description of the Initiative

The approach was to integrate sustainable, resilient, and inclusive principles across infrastructure lifecycle phases of planning, delivery and management. During the planning phase, adaptation was made to existing designs to enhance the resilience of the school facilities. Based on the geotechnical and topographical surveys for the selected schools, the project adapted existing designs of the Ministry of Education, Science & Technology (MoE) to enhance resilience to identified hazards of earthquakes, cyclones, floods and landslides.

There was a strong emphasis on gender and inclusion. Designs for female toilets incorporated requirements to allow pupils to dispose of menstrual sanitary waste in an easy, discreet and hygienic manner. The project also proactively engaged women as part of the workforce throughout the construction. Furthermore, schools and toilets were constructed to ensure easy access to wheelchairs. During the delivery phase, school buildings were constructed to ensure earthquake stability and resistance by using steel and sub-beams. In addition, solar energy systems were installed to ensure a sustainable power supply, reducing the dependency on grid electricity. Backup solar power systems were installed to ensure electricity for a minimum of three days of power outages.

The risk of cyclones and landslides were mitigated through a careful geotechnical analysis that aided in identification of 24 sites. Adoption of nature-based solutions such as of vetiver plants around slopes and hilly areas as well as Ashoka and Dhupi tree plantation in flat areas were incorporated to enhance slope stability and mitigate the risk of erosion.

"Rat trap bond" into brickwork was adopted to ensure lower needs for maintenance and insulation and to enhance sustainability in the building design. Terrazzo chip flooring was used to promote durability and increase the aesthetic quality of the buildings. Composite-type PVC roof sheeting (ASP roofing sheets) was used for insulation and reduction of noise during rainfall. Finally, a rainwater harvesting system was installed to collect water from roofs for usage in toilets. The project had collaboration with MoE, the National Reconstruction Authority (NRA), and the School Management Committee (SMC) throughout its implementation.

Learnings and Impact

The reconstruction of disaster-resilient school buildings with toilet blocks has contributed to the post-earthquake recovery. A total of 24 school buildings were reconstructed with 144 new classrooms, benefiting 5,280 students (2,711 girls and 2,569 boys) along with 273 teachers, 216 SMC members, and 451 children with disabilities.

A post-construction assessment carried out by the UNOPS and the government of Norway listed the following key impacts of the initiative:

- Beneficiaries found the building design and safety features to be excellent or very good.
- It was mentioned that the operation and maintenance training helped the school in retaining the attractive look of terrazzo chip floors.
- The rainwater harvesting system was in school gardens, aiding a good natural environment within the premises.
- A few issues related to maintenance and upkeep were also identified, which were later addressed through the development of an Operational Maintenance Manual (OMM) to guide the local SMC. SMC and national authorities were encouraged to include maintenance costs in their annual budget.

The project included a community-based road maintenance program that trained 100,000 villagers on road safety awareness, established a provincial Emergency Operations Centre and three village flood shelters, and refurbished an Emergency Information Centre. Safety school zones were constructed, and 26,000 students were trained in road safety. The implementation of safety school zone helped reduce accidents near schools and promoted participation of teachers, students, and the local community in road safety. The project also trained women on road construction and maintenance and provided them equal access to jobs offered under the project, such as truck monitoring and road measurement and maintenance.

At completion of the first phase in 2016, the project achieved the following: (a) rehabilitated 545.3 km of rural roads in eight provinces; (b) reduced, by 50 percent, the violations of overloaded trucks in the project provinces, mainly by the installation of overload control gates; (c) improved the average roughness of project roads (from 6–14 to 2–3); (d) increased annual operation and maintenance budget for project roads from $275 per km to $320 per km; (e) facilitated potential accreditation by the Ministry of Rural Development of 10 small-scale road contractors; and (f) developed an emergency management system for rural roads, and constructed one Emergency Operations Centre and three shelters in the most vulnerable location in Kampong Thom Province to which all residents at risk can be evacuated within 72 hours after a typhoon occurs.

Co-Benefits of the Initiative:

It was challenging to access remote areas due to the poor road conditions, especially in the mountains during the monsoon season. The weather and road conditions delayed the soil investigation and school site selection process, which in turn hindered the sustainability assessment of each school site. Despite the challenges, remedial measures such as contractual arrangement of civil works were put forward over the conventional way of providing a contract per site, to prevent further challenges.

- The work was split into three sub-contracts separated by building components: 1) main building 2) windows and doors and 3) roofing.
- The new contract strategy aided the primary contractor to focus on the civil works while the fabrication of metal works related to doors, windows and truss works would proceed in parallel at the factory units of the subcontractors.
- The contracts were duly planned to prevent time slippage and delay due to fabrication works.

The COVID-19 pandemic disrupted the project timeline. However, the team was able to expedite the process by engaging additional workers from neighbouring districts, organising working shifts, and acquiring materials in stock in advance. Moreover, COVID-related health and safety guidelines were followed in addition to the standard practices of UNOPS' Health, Safety, Social and Environment management.

The safety of engineers on motorbikes to supervise construction sites in remote areas in the field was an issue. The roads in the remote districts can be unsafe for the riders of motorbikes due to bad weather, landslides, and the lack of means to call for help in case of breakdowns. A preventive safety measure was incorporated to conduct regular maintenance of the motorbikes and continuous monitoring of the road situations between schools, complemented with continuous communication between engineers when starting and finishing their journey.

The insufficient capacity of the schools to conduct regular maintenance posed a challenge. Following the MoE's guidelines, the reconstructed schools were handed over to the SMC, with the schools being responsible for the operations and management of the school buildings. To ensure the schools' ownership in maintenance, following efforts were made:

- Usage of material and designs that required minimal maintenance.
- Sensitization and guidance on maintenance methodologies and OMM for SMCs and stakeholders of respective schools.
- Support in organizing the development of maintenance budget for SMCs for some schools.

Scalability

The project was implemented in Nepal, a landlocked hilly country, highly exposed to earthquakes, cyclones and floods. Therefore, lessons from this project are applicable for contexts with similar recovery and reconstruction requirements.

B3: Retrofitting the Slussen Lock, Sweden

Sweden

Submitted by:
Organization for Economic Co-operation and Development (OECD)

Introduction to the Initiative

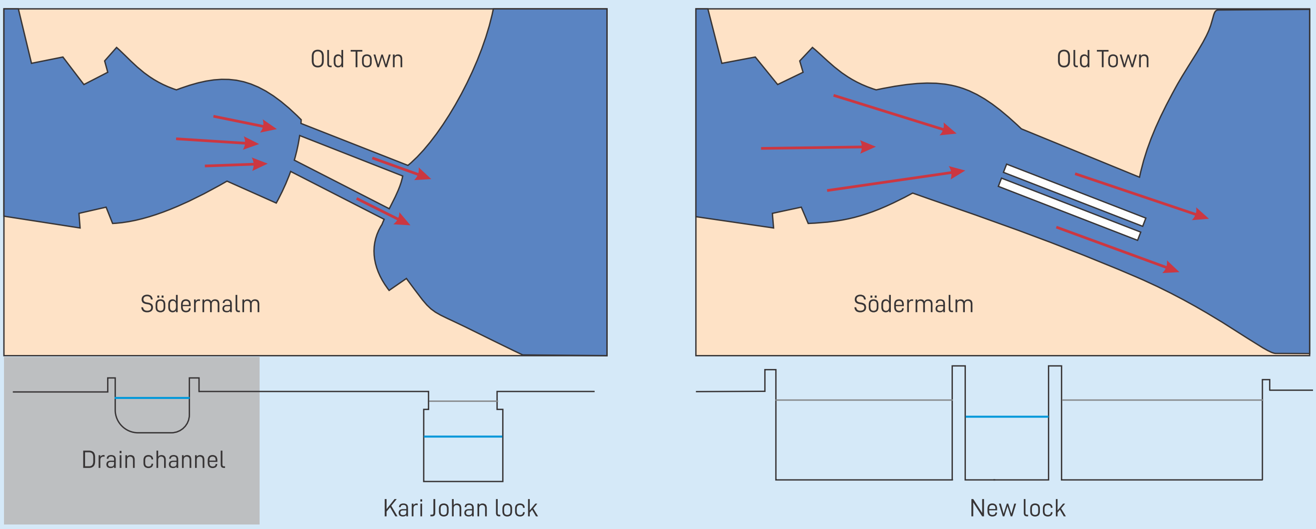
The Slussen Lock is a strategic infrastructure asset for the City of Stockholm and the Mälardalen region. As Sweden's second largest transport hub, it allows boats to transit between Lake Mälaren and the Baltic Sea, and provides a cloverleaf exchange for passenger cars, railway tracks and pedestrian passageways. The lock has a key role in flood prevention, as it can be opened to discharge excess water when the lake waters rise. Furthermore, it ensures clean water access by acting as a gate between freshwater and saltwater.

The project is financed and led by the City of Stockholm. Its goal is to refurbish the current lock, set up in 1935, as foundations have sunk by 25 cm and were at risk of collapse. It aims to address climate risks related to flooding from the lake and sea level rise (considering the parallel land uplift process).

Detailed Description of the Initiative

Based on a vulnerability analysis carried out by the Swedish Meteorological and Hydrological Institute, towns around Lake Mälaren are highly vulnerable to flooding. In 2000, there was a severe flood in Stockholm. As mean water level difference between the lake and the sea is less than 70 cm, there is a risk that even more severe floods could occur due to limited opportunity for excess water discharge.

Several environmental impact, vulnerability and cost-benefit analyses were carried out for the project, resulting in a database listing damage that could occur to critical assets at different water levels, up to around a 1-in-10,000-year flood. Climate and hydrological modelling were also factored into the masterplan for the new lock, including specific considerations to a new water regulation, future sea levels, changing temperatures and dynamic inflow to Lake Mälaren, etc. The climate-adapted new facility will have a lifetime of 100 years.



The improved drainage capacity of the New Slussen lock
Source: Organization for Economic Co-operation and Development (OECD)

Learnings and Impact

The project construction started in 2016 and is expected to be completed in 2025. By enlarging the channels around the lock, the New Slussen will be able to release nearly five times more water from Lake Mälaren to the sea (up to 1400 m^3/s). Accompanied by a new water regulation plan for the lake and responsive hydrological monitoring and forecasting, this will reduce flood risk in Stockholm and the surrounding region.

The New Slussen will be able to withstand the following risks:

- 1-in-10,000-year inflow of freshwater into the lake (e.g., from extreme rainfall and rapid snow melt), combined with mean sea level rise in Baltic Sea by 2100.
- a 1-in-300-year event of maximum high tide position in the Baltic Sea, combined with the highest projected sea level rise in 100 years.

In addition, the New Slussen will ensure the provision of clean drinking water for around 2 million people around the lake, by preventing inundation and saltwater intrusion from the sea. With the redesign of the accompanying transport infrastructure, the project also aims to increase public transport traffic by 26 percent, double cycling and pedestrian traffic, while reducing car traffic by 33 percent by 2030. Furthermore, it will create new green spaces for commercial and leisure purposes for the benefit of locals and visitors, while allowing the lake to become more "natural" and strengthening of ecosystems in the surrounding NATURA 2000 sites.

The following difficulties were identified in course of planning and implementation of the project:

- While planning authorities have consulted on the need to refurbish the lock since 1991, proposed plans often met public contestation.
- Several legal battles, delays and subsequent cost increases have affected the project.
- Disruption to transport services: At the start of construction, close to half a million people used the transport node of Slussen every day. To ensure transport remains operational during the whole project, the construction is carried out in phases.
- Uncertainty around future climate change: Climate flexibility was factored into design by building "oversized" foundations, that can support higher flood gates, if necessary, from 2050 onwards.

C Financing for Infrastructure Resilience

C: Financing for Infrastructure Resilience

Financing resilient infrastructure is crucial for mitigating the impacts of disasters, particularly as climate change increases the frequency and severity of extreme weather events. This theme covers five case studies that highlight innovative approaches to disaster risk financing that strengthen infrastructure, reduce recovery costs and protect vulnerable populations.

The Disaster Ready Fund (DRF) in Australia, established in response to growing climate threats, commits substantial funding for a period of five years to support infrastructure projects like cyclone shelters, seawalls and flood levees. The use of matching funds, with contributions from states and territories, maximizes impact.

The UK's Business of Resilience Taskforce brings together the insurance, engineering, technology, and cyber sectors to develop integrated financial solutions that support governments in managing risks. A notable feature of this case is its focus on bridging the "protection gap" in disaster insurance. By combining infrastructure investments with tailored insurance products, the taskforce enables more effective preemptive adaptation, reducing future costs while increasing the affordability of resilience measures.

The Caribbean Water Utilities Insurance Collective (CWUIC) represents an innovative use of parametric insurance to protect water infrastructure from natural disasters. CWUIC provides rapid payouts to utilities in Caribbean countries after disasters like hurricanes, ensuring quick restoration of essential services. The lesson from this case lies in its scalability and potential for replication, as the mechanism combines risk pooling and reinsurance to cover multiple countries. The rapid payout mechanism demonstrates how financial tools can reduce the recovery time for critical infrastructure and safeguard public health.

The Queensland Betterment Fund, jointly financed by the Australian and Queensland governments, supports the reconstruction of public assets like roads, bridges and drainage systems to a more resilient standard. Since its inception, it has saved millions on avoided reconstruction costs. It demonstrates that upfront investment in resilient infrastructure can reduce long-term expenses while enhancing the capacity of communities to recover from disasters more quickly.

The Caribbean Regional Resilience Building Facility (CRRBF) showcases this by financing projects across the region and providing data for resilience planning. CRRBF supports long-term adaptation strategies that enable technical assistance in building local capacity for disaster risk management, helping governments prioritize investments in resilience.

Key Takeaways

- Government-led financial initiatives such as pre-arranged disaster funds can incentivize mainstreaming resilience in all kinds of infrastructure projects.
- Cross-sectoral collaboration between governments at all levels, infrastructure operators, and financial institutions enables a significantly higher push to resilient infrastructure.
- Parametric insurance is a viable way to increase coverage and improve response time in financing disaster recovery.

C1: Water Utilities Insurance Collective, Caribbean Region

Caribbean Region

Submitted by:

Foreign Commonwealth Development Office, Government of the United Kingdom

Introduction to the Initiative

The Caribbean region is on the frontline of the climate crisis, facing tropical storms, floods and other extreme events annually. These hazards can critically impact essential water services, potentially resulting in water loss, contamination and scarcity, which may have significant health, safety and sanitation implications for vulnerable and disaster-hit communities. The Caribbean Water Utility Insurance Collective (CWUIC) is a new initiative from the UK and other partners, designed to financially protect water utilities in the Caribbean using parametric insurance. It provides rapid payouts after disasters to fund repairs, restore vital services quickly, and offer advice on resilience and rapid response for water utilities.

Detailed Description of the Initiative

Caribbean countries are extremely vulnerable to climate-related disasters. The impact of these disasters – and their effect on vulnerable populations – is also disproportionately high. Climate change is set to increase both the frequency and severity of hurricanes, storms, droughts, floods and other hazards that countries in the region face.

One critical but often overlooked impact of such disasters is on water utilities. These utilities face damage or destruction to key infrastructure and equipment, such as pumping stations and intake valves, which leads to disruptions in potable water supply. This also results in water loss due to damage, leakages, contamination, and sometimes in water scarcity, which can leave entire communities without safe and reliable drinking water. Hazards also affect wastewater disposal systems, with serious health, safety and sanitation implications. A reliable and uninterrupted potable water supply is the key to avoiding waterborne diseases that are often seen post-disaster. Ensuring the quick restoration of water supply is therefore a priority. However, insurance is generally either unavailable or prohibitively expensive, and most water utilities in the Caribbean have limited financial resources to make their existing assets resilient and to restore services quickly post-disaster.

A predictable payout that is released rapidly after a disaster provides water utilities with immediate financial liquidity, which can be used to restore services quickly, improve systemic resilience, and prioritize loss reduction measures.

To ensure the availability of such funds post-disaster to water utilities, the Caribbean Water Utility Insurance Collective (CWUIC) was launched in September 2023, in response to requests from the Caribbean water sector. It is designed to enhance resilience and offer financial protection to Caribbean water utilities against the impacts of extreme weather events. CWUIC is a new partnership between the UK (the Foreign, Commonwealth and Development Office or FCDO) the Inter-American Development Bank (IDB), the Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company (CCRIF SPC), the Caribbean Development Bank (CDB) and the Coca-Cola Foundation.

The initiative offers risk reduction planning and resilience-building investments to strengthen water and sanitation services in the Caribbean, as well as insurance through the Caribbean regional risk pool (CCRIF SPC, formerly the Caribbean Catastrophe Risk Insurance Facility). The insurance provides rapid payouts after disasters such as hurricanes and floods to fund repairs and restore vital water and sanitation services when they are needed most. In keeping with CCRIF's value proposition, all payouts are made within 14 days of the event to allow countries and sectors to begin recovery efforts. Early action is more cost-efficient, preempts damage and enables communities to recover more quickly.

CWUIC has a segregated portfolio within the CCRIF, managed by its own management committee. It is structured to be a comprehensive centre of excellence for disaster risk management and financing for water utilities, going beyond a "traditional" insurance setup. CWUIC has three key components:

- The CWUIC Response Program provides support for emergency response planning and assists in the restoration and rebuilding of facilities post-disaster.
- Parametric insurance for disasters offers swift financial assistance to help utilities respond to and recover from disasters efficiently.
- The CWUIC Resilience Program provides advisory services and technical assistance to identify and structure priority projects aimed at building resilience against natural hazards.

CWUIC is the latest UK investment in a longstanding partnership with the Caribbean to build climate resilience. The FCDO contributed US$5.6 million to help with technical support for shaping CWUIC SP and offering premium subsidies to help the water and sanitation companies in six official development assistance (ODA) eligible Caribbean countries: Belize, Haiti, Jamaica, the Dominican Republic, Guyana and Suriname. Other ODA-eligible countries (including Montserrat) will also receive equivalent price discounts for the first three years.

TUK also provided CWUIC US$25 million in capital, which will be used in combination with reinsurance to protect CWUIC SP against unexpected losses from policy claims. This returnable investment will be repaid after 20 years with no interest. An additional US$650,000 was provided by the CDB and US$739,000 by the CIF through IDB Invest, while the Coca-Cola Foundation provided a grant of US$500,000 for conducting feasibility studies on water utility projects that promote resilience.

CWUIC SP handing over a cheque of US$2.2 million to NAWASA

Learnings and Impact

CWUIC's effectiveness was demonstrated when Hurricane Beryl made landfall in Grenada on 1 July 2024. This powerful Category 4 hurricane caused damage to water and wastewater systems on the mainland and across the islands of Carriacou and Petite Martinique. Grenada's National Water and Sewerage Company (NAWASA) was one of the first utilities to purchase protection from CWUIC prior to the start of the hurricane season on 1 June.

As a result, NAWASA received a payout of US$2.2 million – more than 20 times the premium it had paid – within just 14 days of Hurricane Beryl. It was the first payout by CWUIC since its establishment. This prompt financial assistance enabled NAWASA to initiate recovery operations, restore vital clean water supplies to affected households, and strengthen the resilience of its water systems.

Building on this early demonstration of the role that CWUIC can play, ambition for its potential is high. Almost 35 water utilities in 29 territories in the Caribbean have been identified as potential clients for CWUIC SP, and the team continues to work with several water utility companies in the Caribbean to consider their involvement.

It is expected that five utilities in total will join this year, including Guyana and Suriname, in time for their flood season, in addition to the three existing water utilities. More countries in the Caribbean are also expected to join in future years to benefit from resilience planning support services and substantially lower insurance cost.

As the insurance mechanism is based on a risk pool structure, more members would potentially mean lower costs for everyone. The aim is also to provide cover for more hazards like droughts and earthquakes, apart from just hurricanes and floods. The CWUIC mechanism has great potential for replicability by other countries, and it can be tailored to cover other hazards and sectors as well.

C2: Queensland Betterment Fund: Investing to Create Stronger, More Resilient Communities, Australia

Australia

Submitted by:
National Emergency Management Agency, Government of Australia

Introduction to the Initiative

The Queensland Betterment Fund facilitates the reconstruction of public assets to a more disaster-resilient standard. Jointly funded by the Australian and Queensland governments on a 50:50 basis, the fund has demonstrated that upfront investment in stronger, more resilient infrastructure significantly reduces costs for all levels of government in the face of future disasters.

Since its establishment in 2013 by the Queensland Reconstruction Authority, the fund has supported over 750 projects, with a total betterment value exceeding AUD 533 million (US$358 million) across 70 local government areas in Queensland. These projects have been crucial in enhancing the resilience of communities impacted by severe naturally triggered disasters.

Detailed Description of the Initiative

Queensland is at the forefront of resilience building in Australia, leading through its Betterment programs. These programs enable local governments and state agencies to rebuild essential public assets to a more resilient standard, helping them withstand the impacts of future disasters caused by natural hazards. The Betterment programs are jointly funded by the Australian and Queensland governments under Category D of Australia's Disaster Recovery Funding Arrangements (DRFA) on a 50:50 basis.

The Queensland Reconstruction Authority (QRA) launched the first Queensland Betterment Fund in February 2013, following the extensive damage caused by Severe Tropical Cyclone Oswald. The event resulted in over AUD 1 billion (US$670 million) in damage to essential public infrastructure. Many of these assets had been repeatedly damaged and restored after disasters in 2011 and 2012, only to suffer damage again in 2013.

The 2013 Queensland Betterment Fund allocated AUD 80 million (US$54 million) to allow public assets to be built back better, making them more disaster resilient. This proactive approach aimed to reduce the risk to communities and avoid future reconstruction costs. Assets such as roads, water infrastructure, bridges and drainage systems were identified by local governments as priorities for betterment, providing resilience and risk reduction benefits.

A recent review of reconstruction costs associated with Betterment funding highlights its significant impact. From an investment of AUD 244 million (US$164 million) in projects that were subsequently impacted, an estimated AUD 988 million (US$665 million) has been saved in avoided reconstruction costs. Projects completed since 2017 have already highlighted these benefits, and given Queensland's frequent exposure to naturally triggered disasters, the savings are expected to increase further.

Beyond cost savings, Betterment has greatly improved the lives of communities by ensuring critical infrastructure such as roads and bridges remains functional or returns to service more quickly after a disaster. This faster recovery has a direct impact on reducing disruption and maintaining connectivity for affected populations.

Betterment programs have delivered multiple benefits, including:

- Enhancing the resilience of Queensland communities to natural hazards.
- Reducing future costs associated with asset restoration after disasters.
- Decreasing incidents, injuries and fatalities during and after disaster events.
- Improving the utility and connectivity of assets during and after disasters.

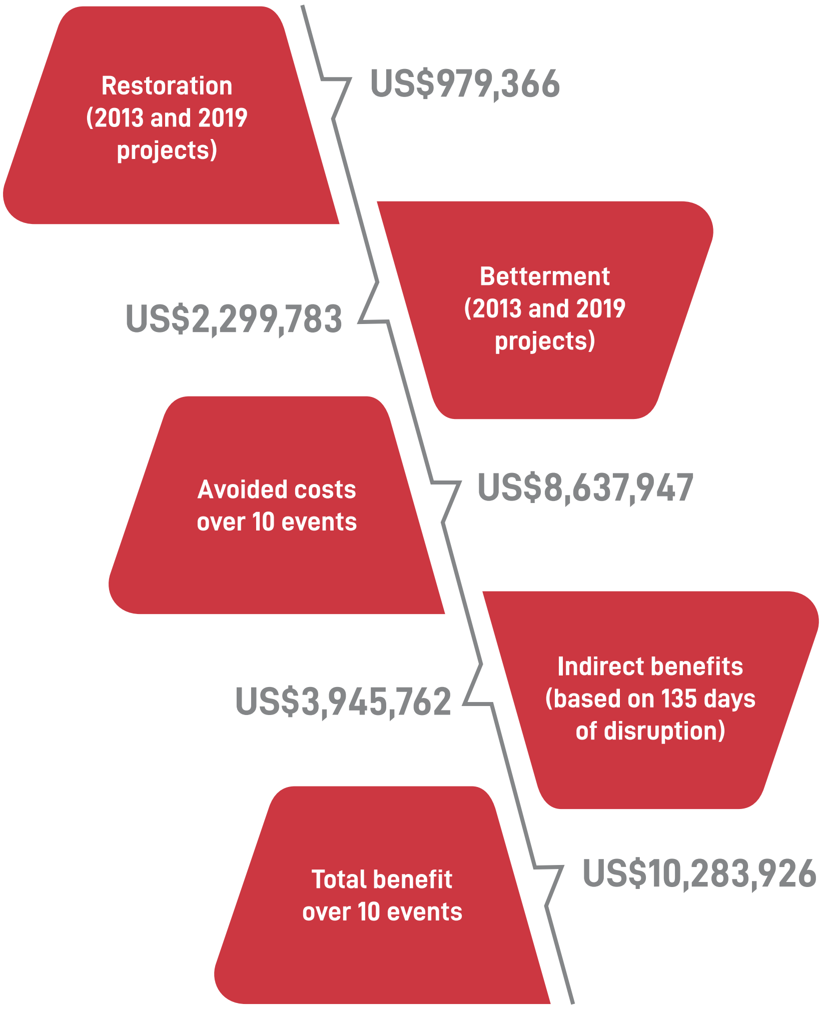
Betterment is a successful example of collaboration across all levels of government to strengthen Queensland's disaster resilience. These programs empower local governments to assess, plan and implement resilience measures, enabling quick action after a disaster to mitigate the impact on their communities.

Example: Aurukun Access Road

Aurukun Access Road is the only road link to the remote Aurukun community in Far North Queensland. It was damaged by naturally triggered disasters in 2010, 2011, 2012 and 2013.

With Betterment funding in 2013, a 10-kilometre section of the road was bitumen-sealed, particularly targeting flood-prone areas. Since then, the road has withstood the impact of 10 naturally triggered disaster events, remaining functional with only very minor damage, making it the most frequently impacted but successfully resilient betterment project to date.

Additionally, US$1.2 million of Betterment funding in 2019 was used to infill scoured sections of the road and stabilize shoulders and embankments. This section endured two major disaster events in 2022.



Aurukun Access Road Before Betterment

Aurukun Access Road After Betterment

Learnings and Impact

The calculated avoided reconstruction costs are based solely on the estimated costs of rebuilding and do not account for the many intangible benefits associated with more resilient infrastructure. These benefits include social, economic and environmental advantages, such as improved community connectivity, continuity of telecommunications and road networks, increased consumer confidence and business activity, and reduced environmental impacts (for example, erosion and runoff into waterways). If these intangible benefits were factored in, the total avoided cost would be significantly higher.

QRA is actively exploring methodologies to better quantify these indirect benefits. In partnership with the International Institute for Sustainable Development, QRA initiated a pilot project to adapt the Sustainable Asset Valuation initiative (SAVi) Tool – an Excel-based cost-benefit analysis model. This tool was customized with 15 tailored indicators, such as road disruption, market access for agricultural products, and mental health, to capture the broader benefits of investments in road resilience.

While this project successfully quantified intangible benefits for infrastructure projects, it also highlighted the need for further refinement of the tool. Significantly, it identified gaps in available datasets and current cost-benefit analysis frameworks, suggesting that more comprehensive methodologies are needed to fully capture the value of resilience investments.

QRA remains committed to working with stakeholders to develop better methods for valuing all the benefits of resilient infrastructure. This will support more informed and effective investment decisions in future projects.

Additional Information

Readings

Queensland Betterment Funds website: https://www.qra.qld.gov.au/betterment

Resilience valuation: https://www.qra.qld.gov.au/resilience/investing-resilience/resilience-valuation

C3: Caribbean Regional Resilience Building Facility (CRRBF), Caribbean Region

Caribbean Region

Submitted by:
The European Union

Introduction to the Initiative

The Caribbean Regional Resilience Building Facility (CRRBF), a partnership between the European Union (EU), the Global Facility for Disaster Reduction and Recovery (GFDRR), and the World Bank, was an initiative that contributed to enhancing long-term disaster resilience and adaptation capacity in the Caribbean region. The CRRBF financed 23 World Bank and recipient-executed projects, which have helped mobilize funding for 29 projects amounting to US$2.09 billion.

The CRRBF pursued its aims through the delivery of technical assistance to mainstream resilience practices, the generation of data critical to informing investment decisions, and the expansion of financial protection mechanisms. Thanks to the work performed under the Facility, actors in the region can exploit deeper knowledge and a wider variety of capacities relevant to disaster and climate resilience.

Detailed Description of the Initiative

The CRRBF encompassed several sectors, including disaster risk management, climate change adaptation, urban planning, and disaster risk financing, all focused on enhancing the resilience of vulnerable states and communities.

The Caribbean region faces numerous natural hazards, such as hurricanes, earthquakes, droughts and floods, many of which are exacerbated by climate change. These hazards threaten the sustainable growth and development of Caribbean countries and require a comprehensive and collaborative response. The CRRBF was implemented by World Bank teams in partnership with EU delegations, regional organizations such as the Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company (CCRIF SPC), and Caribbean governments.

The initiative's implementation involved three operational components:

- Regional Technical Assistance Facility to Mainstream Resilience: This component offered institutional, policy or regulatory advice on a demand-driven basis to enhance administrative and technical capacities for recovery and resilience. In the Dominican Republic, for instance, a project dedicated to resilience in the housing sector elevated the capacity of the Ministry of Housing to design and analyze disaster and climate risk-informed housing policies, leading to the development of targeted housing policies.
- Adaptation Facility for Leveraging Investments in Resilience in the Caribbean: This component aimed to provide evidence-based information to support decision-making on resilience investments. A flood investment project in Guyana, for example, delivered a thorough analysis of the drainage and coastal defence infrastructure, aiding in investment prioritization and enhancing the local government's assessment and planning capacities.
- Expanding Financial Protection Against Disasters in the Caribbean Sovereign Countries: This component facilitated the expansion of CCRIF SPC's insurance and risk-reduction mechanisms, including the design of innovative insurance products and the development of a regional entity for building technology and safety. It also supported the expansion of CCRIF SPC by financing reinsurance costs and improving risk models.

The CRRBF's impact on reducing vulnerabilities and inequalities was significant across the region. By enhancing the capacity to understand and manage risks, updating disaster risk management frameworks, and supporting emergency preparedness, the initiative directly improved the resilience of at-risk populations. Grants supporting infrastructure investments mitigated the vulnerability of crucial structures to natural hazards, while projects dedicated to resilient technologies improved the capacity of authorities to gather information and reach those in need. In this way, the Facility enhanced the disaster preparedness and resilience of several Caribbean governments.

St Lucia 2024, East Coast Road

St Lucia 2024, Piaye Bridge

Learnings and Impact

The implementation of the CRRBF provided valuable lessons on the complexities of multi-sectoral initiatives aimed at enhancing disaster resilience. Projects under the initiative faced several challenges, including coordination difficulties when interacting with multiple local partners and the persistent impact of the COVID-19 crisis, as well as a difficult political environment (Haiti). These challenges were mitigated through proactive project management and flexible implementation strategies.

Efficient coordination was consistently achieved thanks to the efforts of Project Implementation Units (PIUs), which provided direct support to project activities and helped build partner capacity. For example, in St. Vincent and the Grenadines, close collaboration with the PIU and the National Emergency Management Office led to a deeper understanding of their needs and challenges, allowing for timely identification and resolution of bottlenecks. Another method that helped secure effective implementation was ensuring that a project's objectives aligned closely with local government priorities and strategies. As a result, climate resilience considerations could be integrated into existing or developing policies, allowing the project to avoid overwhelming local capacity. Additionally, the CRRBF's ability to adapt to changing circumstances, such as the COVID-19 pandemic and country-specific crises, highlighted the importance of agility in project execution and the need to exploit opportunities to progress projects whenever they arise.

Co-benefits emerged throughout the project, particularly in the form of strengthened emergency preparedness and disaster risk management capacities among stakeholders beyond national government counterparts. This could include actors such as hydromet agencies or academia, and it could extend into the private sector, with a particular focus on the construction industry and insurance sector. This is because the CRRBF strove to foster a culture of collaboration and shared responsibility, leading to more informed decision-making at all levels.

Additional Information

Video Links

GFDRR. (2019). The EU and Caribbean partnership: Working together for a resilient Caribbean. YouTube. https://www.youtube.com/watch?v=Lk4W7MXHS3M

GFDRR. (2019). Voices of Resilience | UR Caribbean Conference. YouTube.https://www.youtube.com/watch?v=gF6qptR2t5A

GFDRR. (2022). The Caribbean Regional Resilience Building (RRB) Facility. YouTube.https://www.youtube.com/watch?v=lytq-6aqj74

GFDRR. (2023). Spotlighting the European Union's support to Disaster Risk Financing across the Caribbean region. YouTube. https://youtu.be/uevl13aNdSQ?si=h6iEFJVjd2IgFUE

Readings

Caribbean Regional Resilience Building Facility Website: https://www.gfdrr.org/en/caribbean-rrb

C4: Business of Resilience Taskforce, United Kingdom

United Kingdom

Submitted by:
Foreign Commonwealth and Development Office (FCDO), Government of the United Kingdom

Introduction to the Initiative

Business of Resilience (BofR) is an industry-led taskforce that spans the infrastructure, insurance, and cyber sectors, and is part of the UK's Business of Resilience programme. The taskforce has worked to identify current strengths and future international opportunities for the UK's resilience sector. The uniqueness of this group lies in the combined UK expertise and joint proposition from the insurance, engineering, technology, and cyberterrorism sectors. The intention is to design and deliver integrated resilience solutions to help anticipate and meet the growing risks to countries and local governments, including those linked to climate change, cyber, and infrastructure challenges.

Detailed Description of the Initiative

Climate change, the COVID-19 pandemic and geopolitical tensions bring into sharp focus the need to improve global resilience. Communities, companies, and countries worldwide regularly face a range of threats such as disasters and cyber breaches. The impact of these events is pushing infrastructure and resilience thresholds to their limit.

No single intervention will be sufficient to deal with the largest disasters, so a new approach is needed as a matter of urgency. It is equally essential that a combined approach to resilience is adopted to manage risks effectively and secure, for example, the maximum value from insurance which will enable averaging of costs triggered by large events, across geographies and time.

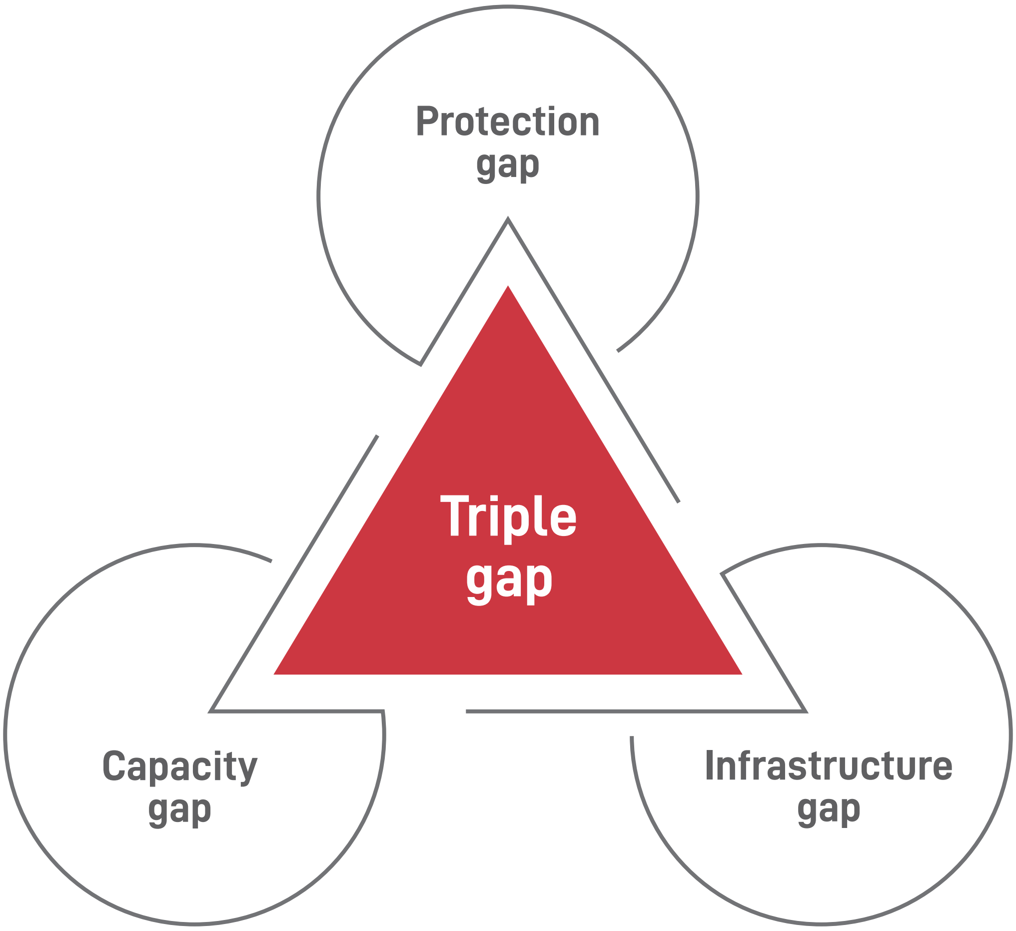
The Business of Resilience is exploring the creation of a new, combined insurance and infrastructure public/private offering that has the potential to enhance how governments invest in resilience. The combination of infrastructure-resilient services, alongside tailored insurance and financial products, should enable governments to better invest in preemptive adaptation that otherwise might have been unaffordable. These investments would potentially mitigate the risks to society and reduce the cost of expensive remediation schemes. The offer would be targeted at mitigating infrastructure risk with holistic solutions that are focused on providing and designing incentive mechanisms for risk mitigation.

Learnings and Impact

Siloed approaches to risk management can lead to gaps in protection. Central to the challenge of building global resilience is the "protection gap" – the gap between economic losses and those that are insured. The global protection gap is 62 percent, which can be much higher in locations where insurance penetration is particularly low – for example, in the Asia Pacific it is 88 percent. This means that millions of households and businesses around the world are exposed to significant risks. As highlighted in the UK government's Resilience Framework, partnerships are necessary to build robust and sustainable infrastructure systems that can respond to external shocks. Developing a combined approach across the infrastructure, insurance and cyber industries can be a foundation to initiate a systematic response to address the disaster resilient infrastructure challenge.

62%

Globally, the average gap between economic losses as a result of catastrophic events and those that are insured



Business of Resilience Infographic, developed by Atkins, Mash MacLennan, and Aon

C5: Disaster Ready Fund, Australia

Australia

Submitted by:
National Emergency Management Agency (NEMA), Government of Australia

Introduction to the Initiative

The Australian Government announced the establishment of the Disaster Ready Fund (DRF) in 2022, in response to the Royal Commission into National Natural Disaster Arrangements which called for greater national preparedness for natural disasters. Under the program, the Australian Government will provide up to 200 million AUD each year over five years, from 1 July 2023, for disaster risk reduction initiatives, with funding expected to be matched by applicants and project delivery partners where possible. The DRF is guided by Australia's national disaster risk reduction obligations and priorities as detailed in the Sendai Framework for Disaster Risk Reduction 2015–2030 and the National Disaster Risk Reduction Framework.

Detailed Description of the Initiative

The establishment of the DRF was secured through legislation. Once the legislation had passed, NEMA worked with all levels of government and community to develop the program guidelines for Round One of the DRF.

Round One was open to state and territory governments (applicants), who have primary responsibility for emergency management, and were expected to work closely with key stakeholders, including local governments and communities, to identify and prioritise suitable projects. NEMA received over 300 proposals seeking over 460 million AUD in Commonwealth funding through Round One. Applications were assessed via a robust and transparent process managed by NEMA in accordance with the published program guidelines.

Round One delivered 200 million AUD in Commonwealth funds for 187 disaster risk reduction projects across Australia. This investment included 65 million AUD for 74 infrastructure projects, 84 million AUD for 74 systemic risk reduction projects, and over 51 million AUD for 39 projects that will deliver both infrastructure and systemic risk reduction outcomes. Funded projects will target a broad range of natural hazards including cyclones, floods, and bushfires through the creation of vital infrastructure such as cyclone shelters, sea walls, flood levees and early warning systems, as well as initiatives that strengthen the resilience of government networks and at-risk communities to the impacts of future natural disasters.

Commonwealth funding was expected to be matched by project proponents, where possible, delivering a combined investment of almost 400 million AUD in 2023–24 to actively reduce the risks and impacts of disaster events and natural hazards, including climate change. Planning for Round 2, which will provide up to 200 million AUD in 2024–25, has commenced with stakeholder feedback and further consultations expected to commence from mid-2023. This provides an opportunity to build on the experiences and outcomes from Round One.

Learnings and Impact

Thousands of Australians face bushfires, floods and cyclones every year. It is known that for every dollar spent on disaster risk reduction, there is an estimated return on investment of 9.60 AUD. The DRF is helping to curb the devastating impacts of natural hazards by investing in important disaster prevention projects. This includes direct investment in grey and green-blue infrastructure, for example flood levees, seawalls and firebreaks.

Projects that target systemic risk reduction to build community resilience and capability were also eligible under Round One. Consultation with states, territories, local government, not-for-profit organizations, First Nations peoples, insurers and other key stakeholders will continue throughout the life of the DRF to ensure strong and constructive collaboration and the achievement of the maximum public benefit possible.

The DRF is given effect through the Disaster Ready Fund Act 2019. It directly contributes to Australia's obligations under the UN Sendai Framework for Disaster Risk Reduction 2015–2030 and Australia's National Disaster Risk Reduction Framework. It is also supported by calls from industry and civil society, such as the Insurance Council of Australia's 2022 *Building a more resilient Australia report*,[16] and the Climate Council and Emergency Leaders for Climate Action's *The Great Deluge: Australia's New Era of Unnatural Disasters*,[17] which have both called for prioritised investment in resilience and adaptation.

Co-Benefits of the Initiative:

Projects under DRF Round One could target a broad range of natural hazards as outlined in the guidelines, and fall within either of the following categories:

Infrastructure projects, including:

- investment in grey infrastructure (i.e., engineered assets such as levees or cyclone shelters).
- investment in green-blue infrastructure (including nature-based solutions).
- investment in hazard monitoring infrastructure; and/or
- business case development for future infrastructure (including investigation, modelling, concept and detailed design activities). Projects in this stream could include flood levees, fire breaks, early warning systems and planning to reduce risk.

[16] Insurance Council of Australia. (2022). Building a more resilient Australia. https://insurancecouncil.com.au/wp-content/uploads/2022/02/220222-ICA-Election-Platform-Report.pdf

[17] Climate Council of Australia Limited. (2022). The Great Deluge: Australia's New Era of Unnatural Disasters. https://www.climatecouncil.org.au/wp-content/uploads/2022/11/CC_MVSA0330-CC-Report-The-Great-Deluge_V7-FA-Screen-Single.pdf

Systemic risk reduction projects, including:

- supporting a better understanding of risk, through a better evidence base to understand and raise awareness of risk
- strengthening decision-making by enhancing the effectiveness of governance networks and communities of practice
- adaptation projects that improve land use planning and development practice projects
- projects that build the capacity and capability of businesses, community organizations and/or at-risk communities to improve their preparedness and resilience to the impacts of future disasters; and/or
- projects that enable and incentivize private investment in disaster risk reduction.

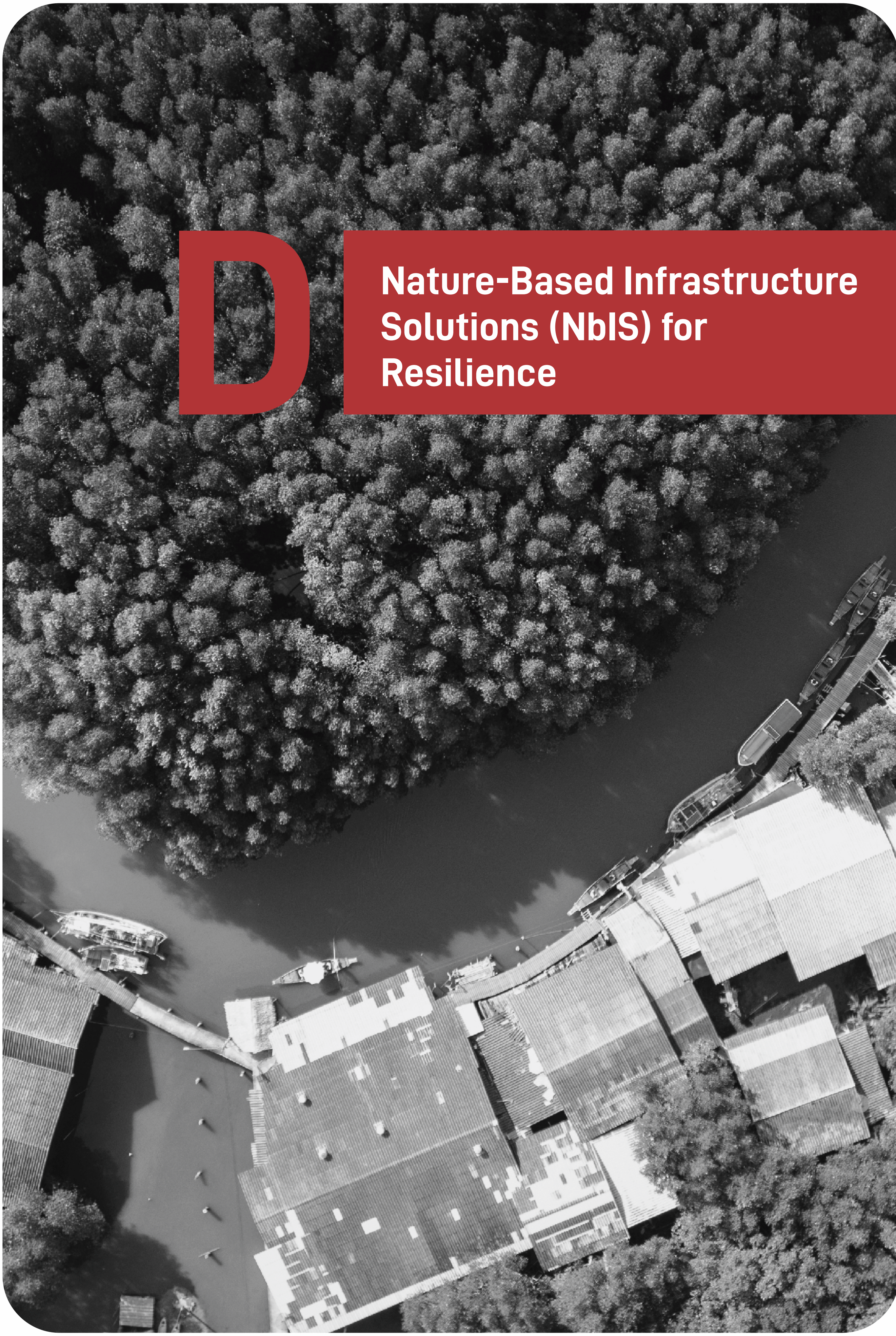
Projects in this stream could include jurisdiction-wide hazard-based information systems, updating resilience strategies, and hazard research.

Round One of the DRF was generally well received by states and territories, and local communities, and feedback from key stakeholders has been largely positive.

Some of the main challenges noted by stakeholders included securing matching funding and meeting the timeframes. The Round One guidelines were released in January 2023 and applications closed in March 2023. Applicants could request a waiver of the co-contribution requirement if they could demonstrate rare and exceptional circumstances. NEMA also received feedback regarding the application process, which involved lodgement through states and territories using an online form developed by NEMA, and the administrative burden on states and territories.

Scalability

Round Two (and future rounds) of the DRF provides an opportunity to address the practical challenges identified through Round One, as well as to consider how the strategic intent of the program can be strengthened. Consultations with key stakeholders will take these issues into consideration as Round Two is designed.



D Nature-Based Infrastructure Solutions (NbIS) for Resilience

D: Nature-Based Infrastructure Solutions (NbIS) for Resilience

Nature-based infrastructure solutions (NbIS) are essential for building resilience in the face of increasing climate-induced disasters. This section draws from four diverse case studies in Hungary, South Africa, and multiple global locations, each highlighting key lessons on how NbIS can strengthen disaster resilience while delivering ecological, social and economic benefits. The thematic insights from these case studies provide a comprehensive view of how nature-based interventions can address challenges ranging from flood management to climate adaptation and community empowerment.

These solutions utilize natural systems to deliver essential services while offering significant economic and social co-benefits. NbIS are often cost-effective, typically costing around 50 less than traditional grey infrastructure. Adopting NbIS jointly with grey infrastructure would influence up to 25 to 44 percent more SDG targets compared to using grey infrastructure alone.[18]

The Cities Challenge Phases 1 and 2, implemented by GIZ, promote sustainable urban development in the Global South through Urban Living Labs. These initiatives empower local stakeholders to address urban challenges with NbIS, exemplified by community gardens in Bangladesh and micro forests in Jordan that enhance food security and community resilience.

In South Africa, the eThekwini Municipality's Transformative Riverine Management Programme (TRMP) exemplifies the benefits of NbIS in enhancing river management across 7,400 kilometres of waterways. By improving water quality and flood resilience, this initiative empowers local communities and over a 20-year period is projected to prevent US$130 million in municipal damage and generate up to US$1.6 billion in societal benefits, including the creation of over 9,000 permanent jobs. The TRMP's focus on ecological restoration not only addresses environmental challenges but also fosters economic empowerment, illustrating how NbIS can create sustainable urban ecosystems.

In the Antananarivo Green Infrastructure and Disaster Evacuation Planning project in Madagascar, NbIS are crucial for improving living conditions in low-income neighbourhoods along the Ikopa River. This comprehensive strategy enhances flood resilience through ecological restoration while strengthening community engagement. The project's phased approach – comprising inception, diagnostics, scenario building, and pre-feasibility – ensured that community insights shaped effective flood risk reduction strategies.

The Flood Protection in High-Density Areas project in Budapest demonstrates how NbIS can manage stormwater and improve biodiversity. Features like rain gardens and swales reduce flooding risks and highlight natural methods for urban resilience. By prioritizing stakeholder involvement and standardized planning, this initiative demonstrates how scalable NbIS can effectively align urban development with environmental health.

[18] CDRI. (2023). Global Infrastructure Resilience: Capturing the Resilience Dividend - A Biennial Report from the Coalition for Disaster Resilient Infrastructure, New Delhi.

Key Takeaways

- Community engagement is crucial in implementing and maintaining NbIS. It boosts resilience by fostering a sense of ownership.
- Institutional collaboration at the local level improves efficiency, fosters improved decision-making, and improves the quality of implementation.
- Merging ecological restoration with socioeconomic development and resilience enhancement creates flexible, scalable solutions and co-benefits.

D1: Cities Challenge Phase 1 and Phase 2

Ecuador Serbia Namibia Jordan Mexico South Africa India Bangladesh

Submitted by:
German Federal Foreign Office, Government of Germany

Introduction to the Initiative

The Cities Challenge, implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), aimed to showcase and support examples for climate-friendly, inclusive, safe, resilient and sustainable cities. Through an ideas competition, each of the two phases (2019–2021 and 2021–2023) identified four urban "living labs" in a total of eight partner countries and supported each with €100,000. With innovative approaches, the initiative improved resilience and quality of life for vulnerable groups, ensured access to public services, and promoted sustainable and integrated urban development.

Detailed Description of the Initiative

In line with its core area strategy of "Responsibility for our planet – climate and energy", the German Federal Ministry for Economic Cooperation and Development (BMZ) fosters an integrated approach to sustainable urban development. This involves close operation with urban stakeholders, including members of civil society, the private sector, and the scientific community. The aim is to leverage the potential of cities to play a major role in global climate and environmental action, contribute to sustainable development, maintain biodiversity, promote gender equality and inclusion, and reduce social and economic inequalities.

The Cities Challenge, implemented by GIZ, aims to ensure that German development cooperation is oriented towards local needs and effective implementation. This initiative seeks integrated solutions for the manifold challenges faced by cities in the Global South, such as risk management, decentralization, water and sanitation, waste management, the circular economy, and mobility.

Woman watering vegetable plants in vertical community gardens made of sustainable materials in an informal settlement in Sathkira, Bangladesh

Installation of PET Bottles on the roof of a community centre in Chennai, India.

In response to these priorities, the eight Urban Living Labs, each supported with €100,000, demonstrate the potential of urban initiatives that collaborate with multilateral and bilateral partners to develop and test new approaches for implementing international agendas. Urban areas offer unique opportunities to accelerate the implementation of global disaster risk reduction, climate, and development agendas while amplifying the necessary impacts. Their spatial integration, potential for cross-sectoral cooperation, human resources, and urban governance create synergies for achieving these goals.

The eight Urban Living Labs are:

- **Portoviejo, Ecuador:** Women in a poor peri-urban settlement acted as guardians to support vulnerable and the sick community members, working together with the municipal disaster management department. With support from students and experts, they secured paths and public spaces from landslides.

- **Amman, Jordan:** An NGO created micro-forests in densely populated neighborhoods, fostering cross-sectoral cooperation and testing novel planting methods to improve air quality, combat heat islands, and create rainwater storage.

- **Windhoek, Namibia:** Residents of an informal settlement created a neighbourhood park to provide a safe and enjoyable space while protecting their homes from seasonal flooding. They also planned the future development of their settlement through a participatory process, supported by the municipality.

- **Belgrade, Serbia:** Food service operators and digital start-ups saved food from being destroyed and provided it to families in need, enhancing urban food security and reducing the burden on landfills.

- **Sathkira, Bangladesh:** The Urban Living Lab improves the living conditions of migrants by creating various types of vegetable gardens. The vegetables will be grown for self-sufficiency and will also be distributed through local sales and an exhibition centre. The Lab will raise awareness of climate change by creating a "Green Public Space" in the central Razzak Park.

- **Chennai and Coimbatore, India:** To address high indoor temperatures above 40 degrees, the Cities Challenge promoted simple, inexpensive and easy-to-implement passive design solutions for roofs. These involve water-filled discarded plastic bottles that act as a daytime radiation barrier and night-sky radiation enabler. Women's cooperatives are provided training, given access to low-interest loans, and supplied with technical support material to replicate solutions in other houses.

- **Los Cabos, Mexico:** The city suffers from water scarcity and recurring hurricanes. Through the Cities Challenge, the neighbourhood is planning and redesigning a park to serve as a natural water basin and implementing reforestation measures with native plant species to prevent erosion. A maintenance plan and a management structure for the park are being developed in cooperation with the local community and municipality.

- **Galeshewe, Kimberley, South Africa:** Traders have been selling their goods under unsafe conditions at makeshift market stalls on the roadside. A small trading centre is now being built with climate-friendly stalls made of locally produced sustainable building materials, such as clay bricks. To supply the market with fresh products, a vegetable garden is being developed in close cooperation with local partners and the community.

Learnings and Impact

Sustainable urban development requires integrated approaches that involve synergies among sectors, actors, and levels of government. Multi-stakeholder partnerships help transfer the concrete implementation of Urban Living Labs to the city level or other municipalities.

The Cities Challenge offered critical insights into urban development and stakeholder collaboration:

- A key lesson was the empowerment of local residents and vulnerable groups, which ensured that the proposed solutions addressed their specific needs and fostered a sense of ownership.
- Multi-stakeholder partnerships were vital in managing the complexities of urban planning. Collaborating with government agencies, civil society, the private sector, and local communities allowed for more comprehensive and resilient outcomes.
- Trust-building with civil society organizations was essential, with transparent communication being key to securing their cooperation and ensuring smoother project implementation.
- The project underscored the importance of integrating lessons learned into manuals and policy guidelines. By documenting and analyzing experiences, the project created a knowledge base that will support future urban development initiatives.
- Another significant takeaway was the need for learning by doing. Implementing integrated urban development solutions is a complex task where practical experience is crucial.
- The project demonstrated that participation in urban planning processes require time, given the need for consensus-building among diverse stakeholders.

The project successfully applied traditional and innovative technologies for low-carbon building materials and nature-based solutions. Urban Living Labs provided a platform for testing and refining these solutions while also establishing trust and credibility in local measures of German development cooperation. The Wuppertal Institute is providing scientific support to refine the methods used in the ideas competition and the labs and to tap additional scaling potential. Several communication materials, such as an Urban Living Lab manual and videos, were created to showcase the scientific angle of Urban Living Labs and their practical implementation in the Cities Challenge.

Additional Information

Video Links

GIZ. (2023). Cities Challenge 2.0 – Building vibrant and resilient neighbourhoods. YouTube. https://www.youtube.com/watch?v=itr82leYv_Y

Readings

CityTransitions. (2024, September 26). What Is the CitiesCHALLENGE About? https://city-transitions.global/transitions-in-action/citieschallenge/

D2: C40 Cities Finance Facility (CFF): eThekwini Municipality – Transformative Riverine Management Programme (TRMP), South Africa

South Africa

Submitted by:
German Federal Foreign Office, Government of Germany

Introduction to the Initiative

The eThekwini Transformative Riverine Management Programme (TRMP), led by eThekwini's municipal authorities in collaboration with local community cooperatives, aimed to scale up river management across 7,400 km of watercourses. This initiative, part of South Africa's broader climate resilience efforts, sought to enhance water quality, mitigate flooding, and protect infrastructure. Over 20 years, the TRMP is projected to avoid US$130 million in municipal damage, generate up to US$1.6 billion in societal benefits, and create over 9,000 permanent jobs. By involving local communities, the TRMP exemplifies a sustainable, cost-effective model for urban ecosystem management.

Detailed Description of the Initiative

The Transformative Riverine Management Programme (TRMP) addresses critical aspects of urban infrastructure, ecosystem services, and community-based economic development. The programme integrates ecological restoration with socioeconomic development, making it a cross-sectoral initiative that bridges environmental sustainability with social equity.

Background and Need for the Initiative

eThekwini is crisscrossed by approximately 7,400 kilometres of watercourses, including rivers, streams and wetlands. Over time, these waterways have suffered significant degradation due to urbanization, pollution, and the invasion of alien vegetation. This deterioration has led to poor water quality, increased flooding, and escalating costs for the city, businesses and citizens. As climate change intensifies, these issues have become more severe, placing greater strain on the city's other infrastructure and increasing the vulnerability of its most disadvantaged communities.

Traditional approaches to urban water management, which often involved reactive and piecemeal interventions, were insufficient to address the scale and complexity of the problem. The need for a comprehensive riverine management strategy was clear.

Implementation and Collaborative Efforts

The TRMP was developed as a proactive response to these challenges. Led by eThekwini's municipal authorities, the programme builds upon existing initiatives, such as the Sihlanzimvelo Stream Cleaning Programme,[19] and expands them to cover all 7,400 km of the city's rivers and streams. This ambitious initiative involves a wide range of stakeholders, including local community cooperatives, environmental NGOs, and various municipal departments responsible for infrastructure, water management and social development.

A key feature of the TRMP is its emphasis on community involvement. The programme employs local community cooperatives to manage and maintain the waterways. These cooperatives are often composed of disadvantaged populations, including women

[19] C40 Cities Finance Facility. The C40 Cities Finance Facility and The Sihlanzimvelo Project, eThekwini. https://cff-prod.s3.amazonaws.com/storage/files/xqwLc2Yla7tFeTSMJFEvYaxu6rT1Ym13S4ekGmqk.pdf

and unemployed youth, who are trained and employed to remove waste and invasive vegetation, restore natural habitats, and monitor the health of the waterways. This approach not only enhances the ecological health of the rivers but also provides a sustainable livelihood for vulnerable communities.

The programme's funding is a mix of municipal resources, national government support and contributions from private sector partners. Over a 20-year period, it is estimated that US$500 million will be required to fully implement the programme. However, the return on investment is substantial, with the programme projected to yield US$130 million in avoided damage to municipal infrastructure and up to US$1.6 billion in societal benefits. Although not priced in, the programme resulted in several biodiversity and nature benefits as well. These societal benefits include improved public health, increased property values, enhanced recreational spaces, and the creation of over 9,000 permanent jobs.

Contributions to Reducing Vulnerabilities and Inequalities

The TRMP is a prime example of how infrastructure initiatives can simultaneously address social and economic inequalities, improving economic prospects and empowering communities to play a crucial role in managing the local environment.

Furthermore, the programme's focus on improving water quality and reducing flood risks has direct benefits for at-risk populations. Low-income communities in eThekwini are often located in flood-prone areas and are disproportionately affected by poor water quality and environmental degradation. By restoring the health of the city's waterways — and thereby the functioning of key natural infrastructure assets/systems — the TRMP reduces these communities' exposure to environmental hazards, thereby decreasing their vulnerability to the impacts of climate change.

The TRMP also promotes long-term resilience by embedding environmental stewardship within the local economy. As the cooperatives take on a greater role in managing the city's watercourses, they help to ensure that the benefits of the programme are sustained over time. This model of community-based management creates a virtuous cycle where environmental health, economic stability, and social equity are mutually reinforcing.

The TRMP represents a holistic approach to urban water management that integrates environmental restoration with socioeconomic development. By addressing the root causes of riverine degradation and involving local communities in the solution, the programme not only protects critical infrastructure and reduces the city's vulnerability to climate change but also contributes to reducing social inequalities. Its innovative blend of ecological and economic strategies makes it a model for other cities facing similar challenges.

Situation before NbIS implementation

NbIS implementation at the municipality

Learnings and Impact

The implementation of the TRMP encountered several challenges, particularly in terms of coordination, capacity-building, and securing funding. One of the main difficulties was the complexity of working across different municipal departments and external stakeholders, each with their own priorities and processes. The CFF played a critical role in overcoming these challenges by facilitating communication and aligning the project with national strategies and donor priorities. The CFF's support was instrumental in creating a viable business case, which helped the project secure funding by clearly articulating the financial and ecological benefits of river management.

Another challenge was the technical and capacity gaps within the local teams. The TRMP required expertise that went beyond the existing capabilities of the municipal staff. The CFF addressed this by providing specialized technical support and resources, which enabled the team to develop a more comprehensive and contextually relevant riverine management strategy. This collaborative approach ensured that the project was not only feasible but also innovative, incorporating both ecological and economic perspectives.

Co-Benefits

The TRMP created significant co-benefits, particularly for marginalized communities living along eThekwini's waterways. By employing local cooperatives, the project provided stable jobs and skill development opportunities, contributing to economic empowerment and social inclusion. This shift in perspective led to stronger support from the city's leadership and laid the groundwork for integrating nature-based solutions into urban planning. Moreover, the collaboration with the CFF helped bridge the gap between environmental concerns and financial viability.

Scalability and Way Forward

The TRMP is designed with scalability in mind, making it a model that can be adapted to other urban contexts facing similar challenges. The key to its scalability lies in its integrative approach, which combines ecological restoration with socioeconomic development. The involvement of the CFF provided a framework that other cities can replicate, particularly in developing countries where financial resources and technical expertise may be limited. Durban established a cross-communal partnership with 17 municipalities to share learnings and build collaboration across a diversity of regional riverine projects.

Moving forward, the focus will be on deepening the engagement with local communities and expanding the programme's reach across more of eThekwini's waterways. The success of the TRMP has also inspired the city to advocate for the adoption of similar approaches in other African cities, highlighting the importance of nature-based solutions as a core component of urban resilience strategies.

D3: Flood Protection in High-Density Areas of Budapest, Hungary

Hungary

Submitted by:
Organization for Economic Cooperation and Development (OECD)

Introduction to the Initiative

Most of Hungary's environmental and climatic challenges are related to water management. In the case of larger municipalities, this often means flood-related issues due to changing precipitation patterns and the high ratio of impermeable surfaces. Extreme weather events such as floods and heat waves in the capital region have the potential to affect a significant share of the Hungarian population.

Detailed Description of the Initiative

In the 16th District of Budapest, the population has grown by 65 percent in the last 70 years. This has resulted in the rise of built-up area and impermeable surface ratio on private and public properties. The vulnerability of the area has further been affected by the area's topography, which allows rainwater from the surrounding areas to drain into the district. This persistently overloaded the combined sewage and drainage system during extreme weather events, and hence the low-lying areas in the district were flooded.

The proposed catchment-based approach was used to change the district's building codes. The approach implemented regulations requiring residential properties to have at least 60 percent of green area ratio to decrease the runoff from private lands. In the case of new government road reconstruction projects, the regulations required that 50 percent of the budget be spent on establishing infiltration trenches to prevent the runoff from surrounding areas from flowing into the district. In areas where the drainage system tends to overload, the implementation of nature-based solutions such as swales, permeable surfaces, and rain gardens were proposed to slow down the runoff. The implemented strategy also prescribed the creation of lakes, creeks and blue-green corridors in such areas. In addition, the municipality invests about €30,000 per year on water retention tanks provided to residents to collect and utilize rainwater.

Nature-based solutions (NbS) were financed and implemented by the municipality, facilitated by a wide range of stakeholder involvement and consultation processes. The municipality also organized public events to raise awareness about flooding.

Insights from the flood protection approach adopted in Budapest
Source: The Organization for Economic Cooperation and Development (OECD)

Learnings and Impact

The rainwater management strategy was implemented in 2006 and various climate change adaptation-related measures have been constantly implemented since then. For instance, some parts of the Szilas Creek were rehabilitated in recent years, and further works are planned to add recreational functions to the area.

Based on the experiences of the municipality, from the time that multiple NbS were implemented, there have been no significant flooding issues during heavy rainfall in the district area. The elevated population density, the high share of developed land (70 percent, compared to 5 to 7 percent in other parts of Hungary) and fragmented land ownership in Budapest made the implementation of larger-scale NbS challenging. However, where planning conditions were homogenous, the same NbS-type intervention was authorized within one process. This standardization simplified the authorization process, decreased bureaucracy, and speeded up NbS implementation. This district-level rainwater management strategy has the potential of being replicated at scale.

D4: Assessment and Pre-Feasibility Study of Green Infrastructure Solutions and Disaster Evacuation Planning and Design to Mitigate Flood Risk and Strengthen Resilience, Madagascar

Madagascar

Submitted by:
Royal HaskoningDHV

Introduction to the Initiative

Antananarivo in Madagascar faces pressing challenges related to urban floods and water pollution, which have wide-ranging impacts on its economy and environment. The integrated master plan, with its focus on nature-based solutions (NbS) and disaster evacuation planning, aimed to enhance flood resilience and living conditions in, specifically, low-income neighborhoods. The project, the design and evaluation of NbS for disaster evacuation and flood risk reduction will contribute to achieving the objective of improving urban living conditions and strengthening of flood resilience in Antananarivo's low-income communities situated along the Ikopa River floodplains.

Mismanagement of solid waste management in the project area
Source: Royal HaskoningDHV

Detailed Description of the Initiative

The project was subdivided into four phases – inception, diagnostic, scenario building and synergies, and pre-feasibility – that resulted in the development of city-level strategic plans for three pilot sites and later recommendations for implementing and upscaling those pilots. The study included continuous stakeholder and community engagement to ensure the robustness of the process adopted for the initiative.

During the inception phase, the project team defined the methodology, technical assessment framework, and community engagement activities, where they held discussions with stakeholders to arrive at a shared understanding of the problem. They conducted field visits to extract site-specific insights and further conducted the diagnostic to understand the current situation, identify challenges and opportunities, and foresee potential solutions. It was concluded that flood risk reduction in the project site of Antananarivo would require a strategic, versatile, multiscale and scalable intervention which would be focused on enhancing the storage and discharge capacity of the floodplains. The interventions would, additionally, require capacity development and awareness generation among affected communities.

Post diagnostic, the team worked on multiple scenarios and synergistic assessment with local economic and environmental development outcomes to explore how different measures and sites could be part of a disaster evacuation plan. They focused on on-site and off-site refuges, connected by a network of evacuation routes, where NbS and other complementary measures could be implemented.

Finally, the team conducted the pre-feasibility assessment to guide the stakeholders working at different scales for implementing and upscaling NbS and other complementary measures for flood risk reduction and evacuation. Three pilot sites were selected and assessed to evaluate the effectiveness of various flood mitigation measures and to develop site-specific plans. These plans included nature-based solutions like urban forests, retention ponds and bioswales. Design guidelines for the upscaling of these pilots were developed, as well as general strategies for their implementation, maintenance, communication and monitoring.

The multi-functional shelter points designed as part of the project
Source: Royal HaskoningDHV

Proposed site: narrow lanes were utilized for evacuation routes as well as NbS planning
Source: Royal HaskoningDHV

Learnings and Impact

The project has strengthened urban resilience in Antananarivo through targeted interventions in urban planning and disaster risk management. The main beneficiaries are the 650,000 poorest and most flood-prone inhabitants of Antananarivo living in high-risk areas. The outcome has enhanced urban living conditions and increased flood resilience in these areas.

Apart from flood mitigation, the nature-based solutions implemented in the project offer additional benefits such as:

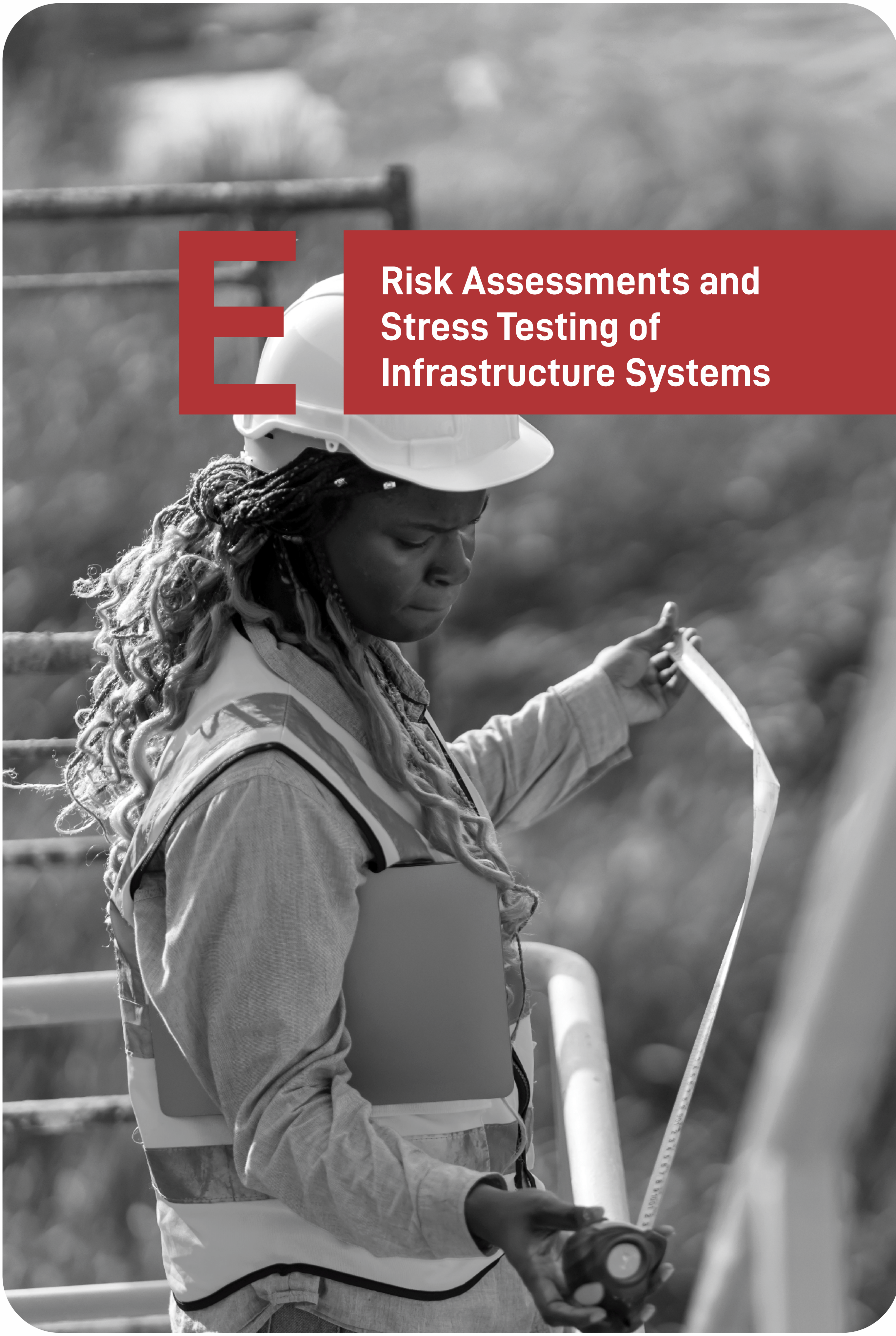
- **Ecosystem Conservation:** The solutions aided in restoring and rehabilitating degraded ecosystems. Conservation of ecosystems enhances disaster resilience and promotes sustainable tourism, fisheries and overall ecosystem health.
- **Community Empowerment:** The solutions involved engaging and empowering local communities. By raising awareness about the value of ecosystems, promoting sustainable practices, and involving communities in decision-making processes, the solutions fostered a sense of ownership and stewardship towards ecosystem conservation.
- **Economic Stability:** By reducing the impact of disasters, the solutions safeguard critical infrastructure, protect livelihoods, and ensure business continuity. This fosters a stable economic environment, encourages investment, and supports sustainable economic growth.
- **Health and Well-being:** The project has helped minimize the health impacts of disasters, including injuries, waterborne diseases, and mental health issues. Enhancing health systems and disaster preparedness contributes to a healthier and more resilient population.
- **Knowledge and Innovation:** This project promoted knowledge sharing, innovation, and capacity building. The exchange of best practices, the development of new technologies, and the transfer of expertise enhanced local institutional capacity, fostered innovation, and supported the development of locally appropriate solutions for disaster management.

Implementation challenges and mitigation strategies

- Engaging and coordinating with diverse stakeholders (government agencies, local communities, NGOs, private sector entities, and international organizations) was a complex task because each stakeholder group had different interests, priorities, and levels of involvement, making it crucial to ensure effective communication, collaboration and consensus-building among them.
- Madagascar has a diverse range of urban typologies, including densely populated urban areas, informal settlements, and rural-urban fringe areas. Each typology presented a unique challenge and required tailored approaches for flood resilience. Understanding the specific characteristics, infrastructure systems, and socioeconomic dynamics of different urban typologies was essential to develop appropriate strategies and interventions.
- Gaining a comprehensive understanding of the water system in Madagascar was crucial for flood resilience planning. This included studying the hydrological patterns, river networks, drainage systems, and flood-prone areas. However, data availability and its quality posed challenges, requiring efforts to collect accurate and up-to-date information. Additionally, local knowledge and indigenous practices related to water management also had to be considered to ensure the effectiveness and sustainability of interventions.
- Madagascar, like many such countries, faces resource constraints and limited capacity for implementing flood resilience projects. Funding limitations, technical expertise shortages, and inadequate institutional capacity may hinder the successful implementation of such interventions. Building local capacity through training programs, knowledge transfer, and institutional strengthening initiatives became crucial to ensure the sustainability of flood resilience efforts.
- It was also important to converge the proposed city strategy plan with various other ongoing WASH (Water, Sanitation and Hygiene) programs in the area to optimize funding and resources in the area. One of these included a Solid Waste Management program funded by the World Bank.
- Additionally, the project gave the project team a unique opportunity to optimize flood evacuation measures as a multifunctional social benefit intervention. This was particularly important due to the availability of open and usable spaces in the densely populated project area. For example, an open space which was designed as a relief and assembly point was also recommended for use as a soccer field during non-emergency situations. These can be seen in the images below.

Scalability

- Climate change introduces an element of uncertainty in flood resilience planning. Madagascar is vulnerable to the impacts of climate change, including increased rainfall variability and sea level rise. It was essential to incorporate climate change projections and scenarios into the project to anticipate future flood risks accurately. This involved considering adaptive strategies such as infrastructure design and land-use planning to address the uncertainties associated with climate change.
- The main conclusion from this pre-feasibility assessment and scaling lessons are that complex challenges require formulating and designing simple solutions that are community-based, easy to implement and are replicable. Moreover, education and a suitable governance structure are essential for the design, implementation and maintenance of successful low-technology intervention for flood risk reduction and disaster evacuation. Scaling lessons for similar interventions pivot around interventions being community-based, being embedded in appropriate governing structures, and supported by appropriate institutional and local capacities.



E Risk Assessments and Stress Testing of Infrastructure Systems

Theme E

E: Risk Assessments and Stress Testing of Infrastructure Systems

Risk assessments and stress testing of infrastructure systems are fundamental steps towards achieving disaster resilience. They empower governments and stakeholders to identify and quantify the risks, including the contingent liabilities, associated with various infrastructure sectors, and help prioritize resilience actions and investments.

Assessing the risk of infrastructure systems includes identification of the probability of hazard events, level of exposure, vulnerability of exposed assets, and assessment of systemic risks that exist due to interdependencies and interconnectedness between various infrastructure systems. The risk assessment methodologies have in recent times evolved with customized approaches and tools to address various aspects of risks, at different scales and at different levels.

This section draws insights from 10 diverse case studies, highlighting the importance of comprehensive risk assessments and stress testing. The case studies showcase good practices and draw key lessons for assessing infrastructure risks and further use the risk information for long-term infrastructure resilience planning. The case studies highlight the need for fostering collaboration and building local expertise for ensuring risk-informed infrastructure development.

The case study on the Physical Climate Risk Assessment Methodology (PCRAM) tool developed by CCRI explains how the tool can be applied to any physical asset or a portfolio of assets for any set of climate hazards. It is designed to enable owners and investors alike to develop their level of maturity in managing climate risks over time. PCRAM allows asset owners and operators to invest strategically and confidently to protect their assets and businesses from climate change.

The case study from France outlines a 10-step methodology for building resilience of transport infrastructure that involves identifying vulnerabilities, analyzing climate projections, and prioritizing adaptation measures. This systematic approach is crucial for ensuring that the critical infrastructure remains functional under various climate scenarios.

The case study from Ghana provides an example of how risk assessment can help governments prioritize their climate adaptation measures. The government of Ghana conducted a robust risk assessment by using advanced geospatial tools to identify the vulnerabilities across multiple infrastructure sectors (energy, water and transport). Tools like the National Infrastructure Systems Modelling Tool (NISMOD) and Capacity Assessment Tool for Infrastructure (EnABLE) were used to analyze risks at an asset level. The findings of the risk assessment helped the government prioritize 35 projects that focused on addressing infrastructure vulnerabilities due to climate change.

The case study on the Global Infrastructure Risk Model and Resilience Index (GIRI), from CDRI provides an example of a robust, publicly available probabilistic risk model that can help countries assess the impacts of geological and hydrometeorological hazards on key infrastructure sectors globally. GIRI's ability to quantify potential future losses can help countries to develop long-term resilience frameworks for various infrastructure sectors and mobilize finances for the same.

The case study on the Climate Risk Assessment Tool developed by the International Energy Agency (IEA) provides a robust framework for evaluating climate hazards affecting energy systems globally. By integrating IPCC climate data and geospatial analysis, the IEA helps stakeholders assess vulnerabilities across energy assets such as power plants and fuel supply chains. This tool has been instrumental in supporting risk-informed decision-making, including recent work in regions like Southeast Asia, where energy infrastructure faces severe risks from rising temperatures, floods and sea level rise.

The case study on the ACeBS system by Indonesia showcases a simple tool to conduct rapid visual screening of building vulnerabilities to earthquakes. This community-based tool has empowered local populations to assess their homes' resilience, ensuring that disaster preparedness extends to all regions.

The case study from UNDRR-CDRI and Bangladesh provides insights on the methodologies for stress testing. The UNDRR-CDRI case study provides a detailed account of the various steps to be undertaken to conduct stress testing. The case study on Bangladesh highlights the steps followed for stress testing critical infrastructure (transport, energy, water and social infrastructure) against climate-induced risks.

The case study from Brazil provides a detailed account of the risk assessment methodology used by the Brazilian National Waterway Transportation Agency (ANTAQ) to assess the vulnerabilities of 21 ports in the country and identify appropriate adaptation strategies to secure the country's trade and economic stability. The ports in Brazil are highly vulnerable to increasing incidences of climate hazards such as flooding, erosion, and intense storms, posing a severe threat to operational stability.

Key Takeaways

- Risk identification and quantification are primary inputs required for infrastructure resilience planning and investments.
- Infrastructure risk assessment requires a systemic approach due to inter-dependencies that exist between the various kinds of infrastructure.
- Probabilistic infrastructure risk modelling can help understand the future risks and support the development of long-term resilience frameworks for various infrastructure sectors.
- Stress testing is a critical tool for evaluating how infrastructure performs under extreme conditions. Stress testing tools and frameworks can help countries quantify the potential losses and inform their contingency planning.
- Use of technologies can support accurate, up-to-date information on vulnerabilities, leading to better decision-making for infrastructure resilience.

E1: PCRAM Assessment: Run-of-River Hydropower Facility

Global

Submitted by:
Foreign Commonwealth Development Office, Government of the United Kingdom

Introduction to the Initiative

The Physical Climate Risk Assessment Methodology (PCRAM) is a one-of-its-kind methodology for improving the integration of physical climate risks (PCRs) into investment appraisal practices. The methodology was applied in three cases in its first iteration and one of the assets was a run-of-river hydropower project in the African region. This work was carried out pro bono as a best practice industry collaboration. PCRAM is intended to remain a public good which can standardize the process for implementation of resilience investment to infrastructure assets. By capturing and quantifying the value of resilience measures throughout an asset life cycle, PCRAM could enable value creation through more reliable cashflows and cost optimization, supporting approaches to monetizing resilience benefits, and can have a positive impact on credit quality and the cost of capital of resilient assets.

Detailed Description of the Initiative

PCRAM was conceptualized and developed by the Asset Design and Structuring working group of the Coalition for Climate Resilient Investment (CCRI) in association with the engineering, development and management consultancy Mott MacDonald. This methodology was a response to a growing demand from investors who wanted comprehensive solutions for improving the integration of physical climate risks (PCRs) into investment appraisal practices. Apart from the above institutions, 35 other institutions, ranging from banks, investors, engineering firms, climate risk data providers, lenders, credit rating agencies and academic institutions, supported the development of PCRAM – making it a cross-industry effort to advance a dynamic impact assessment of physical climate risks that can be incorporated into investment decision-making.

PCRAM brings together climate science, asset management, resilience practitioners and financiers to assess, design and quantify the resilience needs of infrastructure assets. It can be used to identify material physical climate risks to an organization's assets and build resilience to improve performance and protect revenue. PCRAM helps decision-makers understand benefit-to-cost ratio and target investment, and to plan programmes of investment that align with existing organizational and regulatory investment cycles. This methodology can be applied to any physical asset or to a portfolio of assets, for any set of climate hazards. It is designed to enable owners and investors alike to develop their level of maturity in managing climate risks over time. PCRAM allows asset owners and operators to invest strategically and confidently to protect their assets and businesses from climate change.

The first iteration of PCRAM methodology was applied to three assets and the work was conducted by multidisciplinary teams. These assets were chosen to demonstrate PCRAM's potential broad applicability to a variety of infrastructure assets in different locations, across financing and ownership models, each faced with different climate risks. As a part of these assessments PCRAM was used to model cashflows by integrating the impact of physical climate risks to understand "valuation at risk", which provides a clearer picture of the materiality of asset-specific physical climate risks. This is different from the climate "value at risk" assessments used in the insurance industry. Taken together, they showcase several potential applications for the analysis, exhibiting the value of robust and standardized physical climate risk assessments to all stakeholders.

One of the three assets where PCRAM methodology was utilized was a hydropower facility in the African region. An investment was made in development funding of an approximately 40MW capacity run-of-river hydropower project. The asset had a lifetime of 40 years and an average annual energy generation of roughly 200GWh/year. During the scoping and data gathering process a series of asset objectives were compiled by reviewing the available asset data, and global and regional climate projection models were analyzed and utilized to identify potential climate hazards in the area. Given the nature of the asset (being dependent on precipitation and river discharge) and the preliminary climate screening, this study focused on the materiality of drought risk (both acute events and chronic changes in precipitation). Hence, the climate variables analyzed were drought and precipitation.

During materiality assessment two future climate horizons analyses were conducted to estimate the chronic risk associated with changes in annual precipitation. These were then utilized to adjust the existing hydrological model. This adjusted hydro-model was then fed into an energy model to calculate the expected change in energy generation. The future climate projections revealed minimal reduction in river discharge through to 2040 and a 15 to 20 percent reduction in discharge from 2040 to 2060.[20] The next step was resilience building in which several potential structural and functional resilience measures and their impact on capital expenditure (CAPEX) or operating expense (OPEX) were identified. Resilience options suggested for this hydropower plant were a new access road, flexible intake design, variable flow turbines, and slope design/monitoring.

Finally, an economic and financial analysis was done for a 20-year-period to align with the initial concession term. Three climate base cases (P90, P75 and P50) were utilized for deriving the internal rate of return (IRR) for each case. The key financial results indicated that the P90 case has the highest IRR due to projected increases in precipitation during dry seasons and a significant impact of a 3-month drought in wet season. Two different outcomes for the asset's lifespan show that there would be lower impact in the near to medium term and a significant material impact in the longer term with an anticipated loss in energy production.

Learnings and Impact

The application of PCRAM methodology on a run-of-river hydropower project in the African region yielded the following learnings:

- The benefits of infrastructure assets are not merely financial. PCRAM is focused on understanding financial costs and benefits and further work may need to be required to integrate for non-monetary benefits of investing in resilience.
- It is difficult to assess the costs and benefits of investing in resilience of a single asset in isolation from the wider system of assets. Resilience often needs to be considered at a systemic scale.
- Expert advice, specifically from climate scientists, is essential before using any climate data.

[20] IIGCC. (n.d.). Case Study 1: Run-of-river hydropower facility. The Institutional Investors Group on Climate Change. IIGCC_hydropower_case_study_final.pdf

The challenges involved in implementing the PCRAM methodology include differing quality levels of due-diligence reporting, lack of funding, and lack of awareness among the stakeholders involved. Apart from these, overdependency on indemnity insurance for some climate-related risks such as flood events and wildfires mean that there is little to no incentive to invest in factoring in resilience against some of the more expected climate impacts such as additional flood protection and adjusting the design to deal with larger volumes of water.

A systemic adoption of PCRAM as a basis for a sound physical climate risk assessment – that includes options for building real world resilience in assets – could spur a shift to resilient investment. This could in turn deliver assets with more predictable future cash flows and/or optimized life-cycle costs, helping build systemic resilience from the "bottom up" in asset portfolios and in the communities in which they operate

Figure E2.1: PCRAM Methodology

Steps	**1 Scoping and data gathering**	**2 Materiality assessment**	**3 Resilience building**	**4 Economic and financial analysis**
Objectives	Determine data sufficiency	Assessing asset resilience	Identifying resilience options	De-risk asset exposure to PCRs
Sub-tasks	• Project initiation • Project definition • Data gathering and sufficiency	• Hazard scenarios • Impact identification • Impact severity • Risk quantification	Resilience options: • Hard (Structural/capex) • Soft (operational/systems)	• Cost/benefit analysis • IRR comparison
Outputs	• Initial climate study • Critical components • KPI selection (the base case)	• Detailed climate study • List of impacts and severity by component • The 'Climate Case'	• Revised climate study for new elements • The "Resilience Case'	• Recommendations • Value implications
Decision gates	**Gate A** **Is data good and sufficient**	**Gate B** **Are PCRs material to this asset?**	**Gate C** **What resilience options are available for this asset?**	

Additional Information

Video Links

Mott Macdonald. (2022). Physical Climate Risk Assessment Methodology (PCRAM). YouTube. https://youtu.be/lG0vPyt9yLI

Readings

Wharton, J. & IIGCC. (n.d.). Outputs from the Physical Climate Risk Assessment Methodology (PCRAM) 1.0 Case Studies. IIGCC. (n.d.). Case Study 1: Run-of-river hydropower facility.

ttps://www.iigcc.org/hubfs/2024%20resources%20uploads/PCRAM/IIGCC_hydropower_case_study_final.pdf

E2: Global Infrastructure Risk Model and Resilience Index (GIRI)

Global

Coalition for Disaster Resilient Infrastructure (CDRI)

Introduction to the Initiative

The Global Infrastructure Risk Model and Resilience Index (GIRI) platform provides detailed risk information on the potential impacts of geological and hydro-meteorological (including climate forcing) hazards on critical and social infrastructure sectors. It is a global advocacy tool for promoting investments for infrastructure resilience. This information can be used by country governments to allocate resources for contingency planning, improving infrastructure codes or standards, and prioritizing long-term infrastructure investments with a focus on climate adaptation and resilience.

Further, using sector and sub-sector loss information from various hazard scenarios, country governments can arrive at the amount of contingency funds that will be required to manage the financial impacts of natural hazards, thereby leading to sustainable and resilient economic development.

Using GIRI data, governments in partnership with the private sector can also develop innovative financial instruments such as catastrophe bonds and insurance schemes. While catastrophe bonds can help in ensuring liquidity and reducing the financial strain on government budgets in the aftermath of disasters, risk-based insurance schemes can incentivize investments in resilient infrastructure.

Detailed Description of the Initiative

With increasing disaster events, the world is witnessing massive destruction of infrastructure assets and disruption of various infrastructure services. When infrastructure is damaged or destroyed, the essential services that people rely on are impacted. New tools are therefore needed to measure and explain the increasing risks from these disasters. Such tools will enable better policymaking and unlock investment, underpinning the value of spending a small additional amount to lock in resilience and unlocking investment, especially from the private sector, which will be able to accurately assess and manage risks across their portfolio.

The Global Infrastructure Risk Model and Resilience Index (GIRI) developed by CDRI is a first-of-its-kind publicly available tool. GIRI enables policy makers and financiers to understand the potential risks to infrastructure in their country.

GIRI can be thought of as a smart atlas: showing different countries and the natural hazards geography-wise and their likely impact on essential infrastructure systems in these countries. The infrastructure sectors included in GIRI are the most critical: power, roads and trains, transport, water and sewage, communication, oil and gas, education, health, employment and housing.

To more effectively integrate risk and resilience into fiscal and financial public sector planning and systems, it is essential to embed risk information into the decision-making process. Risk identification and quantification are primary inputs required for effective fiscal risk planning. While various data platforms provide information on economic risks, information in the public domain on the economic costs of impacts likely to emanate from natural hazards used to be limited.

This information from GIRI gives an overview of the potential risks due to natural hazards for a country's infrastructure. For example, Bangladesh faces significant flood risks. GIRI indicates that over 90 percent of infrastructure losses in Bangladesh are due to floods. Additionally, it helps to understand the risk for specific sectors. For instance, the transport sector in Bangladesh experiences nearly two-thirds of annual losses due to floods.

CDRI is now using GIRI data to inform its Fiscal Risk Assessment (FRA) study where the data is being utilized to estimate the direct physical risks posed to infrastructure assets due to disasters (including climate change-related disasters). The FRA study covers four countries namely Fiji, India, Mauritius and Nepal. The International Water Management Institute (IWMI) is utilising GIRI data to amplify their Climate Smart Governance (CSG) dashboard so that government agencies and financial institutions could prioritize investments by utilizing GIRI indicators to assess the vulnerability and resilience of critical infrastructure.

Further, five countries, namely Bhutan, Chile, Ghana, Madagascar and Tonga, are in the process of using GIRI data to prioritize their infrastructure governance. Institutions like the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) and the United Nations Office for Disaster Risk Relief (UNDRR) are also using GIRI within their country engagement and risk assessment projects and programs. In addition, there has been interest from financial institutions for using GIRI as a model for calculating their assets/investments at risk.

Learnings and Impact

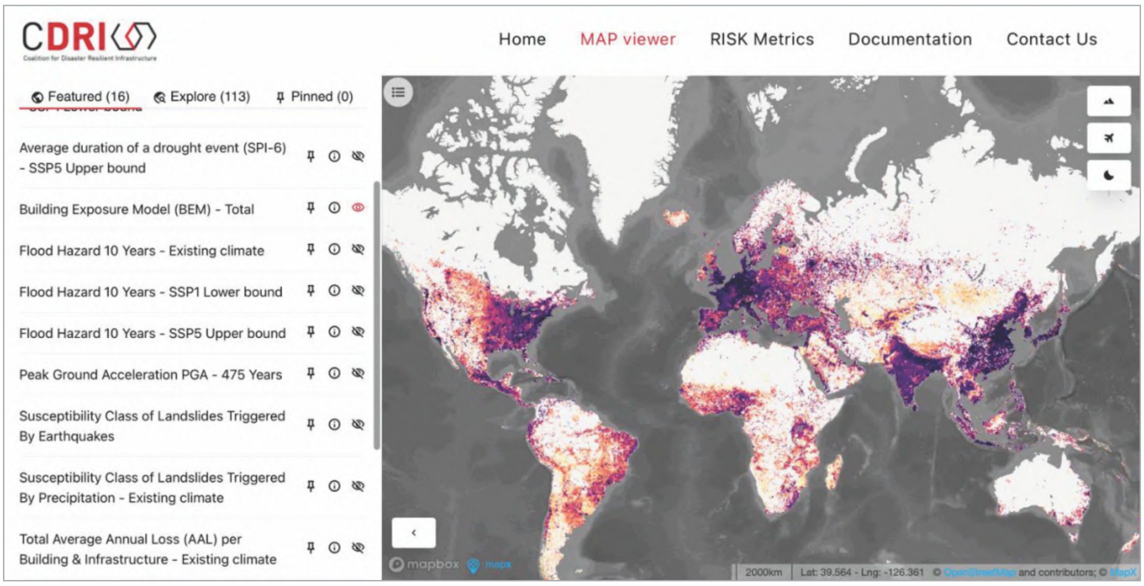
One of the key challenges is that while infrastructure risk information generated by GIRI is made available to users in the open-source open data format, it is sometimes difficult for decision-makers to apply it to their requirements. This is mainly because of a lack of understanding across most of the stakeholders in using such information in the past for their work, predominantly due to the unavailability or inaccessibility of such data and information. CDRI is trying to overcome this challenge through targeted training programs and awareness sessions to country governments and member partners. It is also trying to communicate the importance of the risk information and possible use cases through webinars, conferences and other international and regional forums.

Such engagements have shown that stakeholders who can benefit from the process include national and regional governments (especially their financial departments), disaster management agencies, infrastructure planning agencies, public works departments, development banks, financial institutions (public and private), NGOs, multilateral agencies such as UN, and academia and researchers.

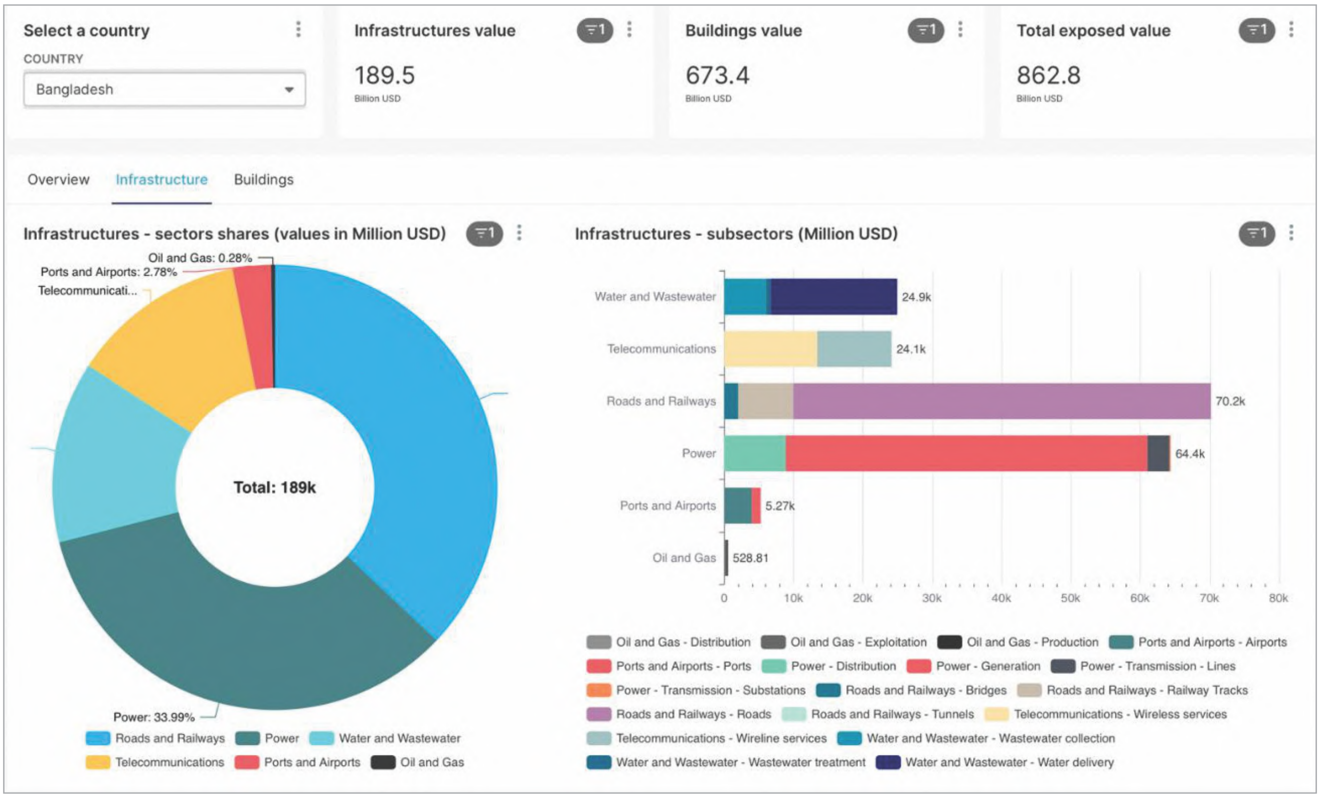
The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) leverages data from GIRI to support risk-informed decision-making and enhance disaster resilience across the Asia Pacific region. This includes integration of GIRI into the monitoring of countries' progress in the areas of disaster and climate-related Sustainable Development Goals (SDGs).

Data for average annual losses (AAL) from GIRI is being used to inform the Asia Pacific Disaster Report (APDR) and subregional APDRs, which are currently shaping government policies and supporting regional and subregional cooperation. In Nepal, Cambodia and Tajikistan, UNESCAP is downscaling GIRI's climate hazard risk data to more granular levels. ClimaWise, an AI-powered adaptation tool developed by ESCAP, utilizes GIRI data to provide guidance for adaptation planning.

While GIRI provides a global database of risk information across six key hazards and eight critical social infrastructure types along with two climate scenarios, there is a huge potential for scaling the model. This can be done by introducing new hazards within the platform such as heat waves, cold waves, glacial lake outburst floods, lightning strikes, volcanos, air pollution, etc. In addition, the platform can also include more asset information and downscaled risk information to address issues within urban areas and small islands. This will enable the platform to be more comprehensive and act as a one-stop shop for infrastructure risk information for governments and communities at large.



GIRI Data Platform Interface



Country-wise total exposed value data

Additional Information

Video Links

CDRI. (2024). GIRI. YouTube. https://www.youtube.com/watch?v=FU0fDtvpfIU&list=PLBnqRELxRJS-3mVu6oE5Gku7N9eZarRG7&index=1

Readings

CDRI. (2023). GIRI Documentation. https://giri.unepgrid.ch/search-documentation

CDRI. (2023). Global Infrastructure Resilience: Capturing the Resilience Dividend - A Biennial Report from the Coalition for Disaster Resilient Infrastructure, New Delhi. https://www.cdri.world/upload/biennial/CDRI_Global_Infrastructure_Resilience_Report.pdf

E3: Climate Risk Assessment Tool for Energy Systems

Global

Submitted by:
International Energy Agency (IEA)

Introduction to the Initiative

As climate change intensifies, extreme weather events and shifting climate patterns increase disaster risk and can significantly impact the energy value chain and infrastructure. To safeguard energy security, the International Energy Agency (IEA) developed a tool to provide climate risk assessments of energy systems to better inform decision-making of stakeholders.

Detailed Description of the Initiative

Climate change-related impacts and disasters are likely to grow and intensify in the coming decades, threatening global energy production and consumption and putting energy security at risk. Heat waves, floods, droughts, tropical cyclones and rising sea levels pose challenges to the energy system. To ensure energy security, the energy value chain and infrastructure need to be climate resilient. The IEA developed a tool to conduct climate risk assessments in the energy sector and has put forward several publications using this methodology. These include global insights in Climate Resilience for Energy Security (2022) and regional insights, most recently, in Climate Resilience for Energy Security in Southeast Asia (2024).

The climate risk analysis involves evaluating: 1) climate hazard risks using climate data from the Intergovernmental Panel on Climate Change (IPCC); 2) exposure levels, which measure how much a particular type of energy asset or infrastructure could be affected, using IEA GIS analysis and; 3) vulnerability, which assesses the sensitivity of these assets to the identified climate hazards as well as their capacity to cope with and adapt to these hazards.

The tool is using climate data from IPCC for three different emission scenarios (below 2°C, below 3°C and above 3°C) and for three different time frames (2021–2040, 2041–2060 and 2081–2100). Each climate hazard is thoroughly examined using multiple climate variables such as temperature, precipitation, wind, and sea level rise, analyzing historical trends as well as projections. Using geospatial analysis, the climate data is combined with data on energy assets and infrastructure to perform climate risk assessment. The analysis includes fuel and critical mineral mines, different types of power plants, and the electricity grid.

Further extending the methodology, IEA provides climate impact assessments (Figures E3.1 and E3.2) based on qualitative research and expert consultations and identifies resilience measures to inform decision-making and to promote the adoption of resilient practices in designing, planning, constructing and maintaining energy systems.

By reducing the risk of energy disruptions and enhancing the overall security of energy systems, the climate resilience work of IEA in the energy sector plays a crucial role in ensuring that all populations have access to reliable energy in the face of the increasing threat of climate-induced disasters.

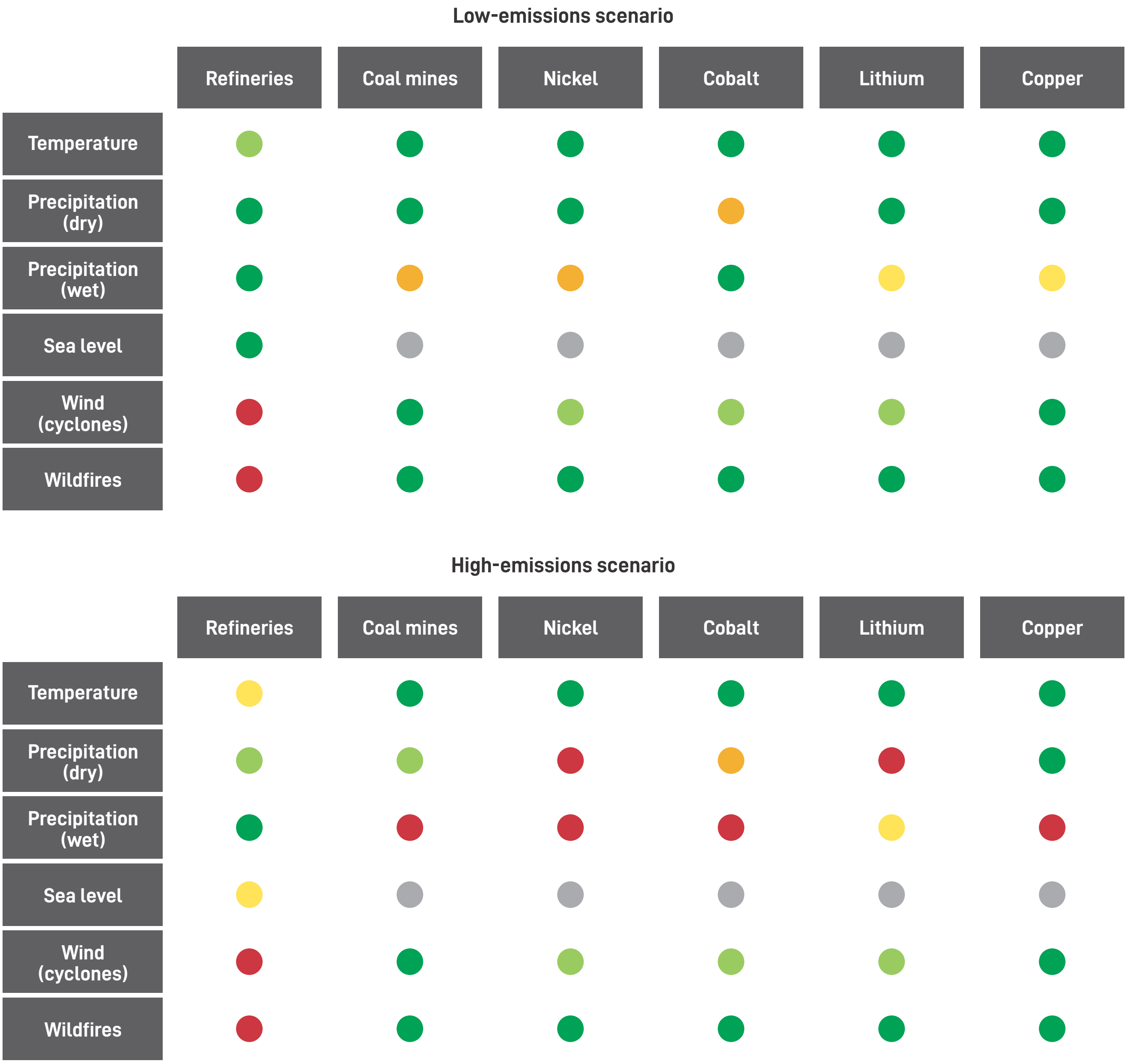
Learnings and Impact

The climate risk assessment methodology developed by IEA helps assess the impacts of climate change on the energy sector across global, regional and country-specific levels. This directly benefits stakeholders in planning new sites and implementing disaster mitigation strategies like investing in advanced technologies and reinforcing infrastructure to withstand climate hazards. Robust climate risk assessments also help stakeholders to develop and adopt policies and regulations that promote resilience of the energy sector and inform the creation of codes and standards.

Building and fostering climate resilience in energy systems generates significant co-benefits, particularly in sectors like health, environment, water, education and industry, and for vulnerable communities by avoiding the socioeconomic impacts of climate-related energy interruptions. For example, in the health sector, resilient energy systems minimize disruptions to hospitals and medical supply chains, ensuring the continuous provision of essential care during extreme weather events and disasters.

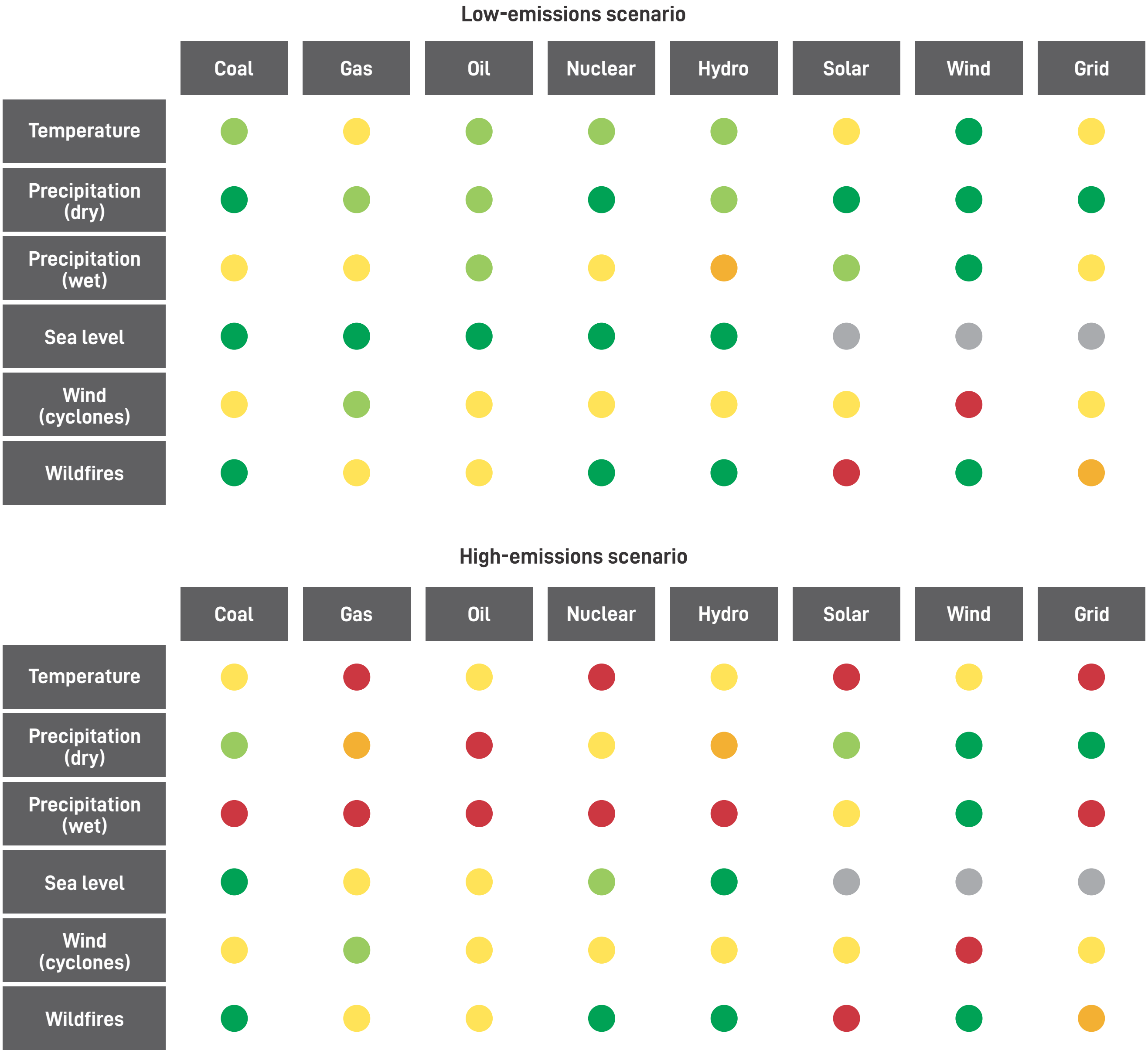
The IEA looks to further scale and strengthen its analytical work on climate risk and impact assessment tools to building disaster- and climate-resilient energy systems and collaborating with stakeholders from industry, international organizations and governments.

Figure E3.1: Comparison of global climate change risks to fuels and minerals in the low-emissions and high-emissions scenarios, 2080–2100



Note: The levels of climate risks are divided into five categories, from dark green for low risks to red for high risks. Grey dots indicate no information.

Figure E3.2: Comparison of global climate change risks to power systems in the low-emissions and high-emissions scenarios, 2080–2100



Note: The levels of climate risks are divided into five categories, from dark green for low risks to red for high risks. Grey dots indicate no information.

Additional Information

Readings

IEA. (2022). Climate Resilience for Energy Security. International Energy Agency. https://iea.blob.core.windows.net/assets/10229b31-fd82-4371-b92c-a554f95369ea/ClimateResilienceforEnergySecurity.pdf

IEA. (2024). Climate Resilience for Energy Security in Southeast Asia. International Energy Agency. https://iea.blob.core.windows.net/assets/4c5449ca-edde-4c54-8b86-61616c7c8c64/ClimateResilienceforEnergySecurityinSoutheastAsia.pdf

E4: Utilizing ACeBS to Conduct Mass Rapid Visual Screening (RVS) to Identify Potential Building Vulnerabilities towards Earthquakes, Indonesia

Indonesia

Submitted by:
National Disaster Management Authority, Government of Indonesia

Introduction to the Initiative

Over the past two decades, Indonesia has experienced a significant amount of damages to houses due to earthquakes. Between 2006 and 2023, at least 821,700 homes were affected by earthquakes, with damage categorized in all levels of severity. This has led to substantial direct economic losses of approximately 85 trillion rupiah (US$5.5 billion). This has also jeopardized the livelihoods of the affected communities and the progress of national development. A major challenge in strengthening infrastructure resilience against disasters in Indonesia is the community's lack of awareness and insufficient institutional capacity to enforce earthquake-resistant building standards. This is further amplified by the sheer volume of the country's population, which is the fourth-highest in the world and needs millions of new disaster resilient homes, including retrofitting existing homes. Furthermore, Indonesia also doesn't have dynamically mapped data on building vulnerability, which is important to calculate disaster risk more accurately. To overcome these challenges, the Indonesia National Disaster Management Agency (INDMA) in collaboration with Prof. Dr Sarwidi Earthquake Museum has created a computer application called ACeBS. This application addresses the need for rapid assessment of housing vulnerability towards earthquakes through a community-based approach.

Detailed Description of the Initiative

Indonesia's geographical location makes it highly susceptible to earthquakes due to tectonic movements. About two-thirds of Indonesia is prone to earthquakes and on average, at least one major earthquake occurs almost every year. Strong seismic shaking can destroy buildings – particularly homes – resulting in significant loss of life and property. Research shows that housing failure with regard to earthquakes is mostly linked to buildings not adhering to proper building codes and standards. There are millions of houses in Indonesia which do not adhere to codes, and more than one million houses are built every year without supervision or control by government agencies.

To address this issue, a series of anticipatory measures have been undertaken using the disaster risk reduction (DRR) approach, which includes collecting risk information, reducing vulnerability, and capacity building. Although structural strengthening of houses is considered to be the most effective solution, it requires a substantial amount of funding, which is a challenge for the government. Therefore, one possible way is to disseminate knowledge regarding earthquake-resistant houses and strengthen community engagement for building assessment. To engage the community to conduct vulnerability assessment of houses, the Asesmen Cepat Bangunan Sederhana (ACeBS) application was developed in Indonesia in 2018. It is a novel as well as the only available solution to map building vulnerability across the country.

ACeBS employs the Rapid Visual Screening (RVS) method, through which the vulnerability of buildings and houses in earthquake-prone areas is assessed on a large scale. The application also helps in raising awareness and promoting a strong, safe and integrated, earthquake-resilient building system – with both structural and non-structural components – and encourages its implementation within communities.

RVS provides an initial assessment of a building's seismic performance without requiring structural analysis. It helps identify buildings which are at risk of failure during earthquakes by analyzing data on construction materials, application of seismic resistance systems, and relevant building attributes. Data is collected on-site through observations documented on forms. This method can be used to assess a single-storey building and also any 2 to 4-storey building of C3 category – which are buildings with reinforced concrete structure with infill walls without reinforcement – as designated by Federal Emergency Management Agency (FEMA).

The ACeBS application is also featured in thr InaRISK personal application, an umbrella platform for individual risk assessment in Indonesia that is widely used by the community. The app is available for Android and iOS users. Leveraging the widespread availability of smartphones and advanced mobile internet technology, the application empowers individuals to evaluate the safety of their homes. Through a user-friendly interface, ACeBS also provides educational resources and guidance on earthquake preparedness. By encouraging community engagement and fostering awareness, the application aims to enhance resilience and reduce the potential impacts of earthquakes.

The ACeBS application has been utilized for various capacity-building activities and has also benefitted from them. A technical training on ACeBS for the local disaster management agency and surveyors in D.I. Yogyakarta Province was conducted in August 2019. The province has had one of the most devastating earthquakes in Indonesia in 2006: a 5.9 seismic rating earthquake which resulted in more than 5,000 casualties and 200,000 damaged houses, making it urgent to implement policy level changes to achieve disaster resilient infrastructure. The training was attended by 135 participants and aimed to improve participant's knowledge on earthquake-resistant building codes, including tutorials to operate ACeBS. A similar training was conducted in August 2019 in Bandung Wes Jawa, which was attended by 40 participants.

In December 2019, another training with a field-assessment component was also conducted in Aceh province. This province had the most casualties from the Indian Ocean tsunami of 2004. The pilot survey included 27 villages from three subdistrict areas of Jagong Jeget, Bebesen and Kebayan. A total of 173 houses were evaluated by 27 facilitators coordinated by the local government. Through this assessment activity using the ACeBS application, the local community was able to learn the status of resilience of their houses. Some community members also directly installed the ACeBS application with the help of the field personnel and facilitator. The application is convenient to use and understand as it also includes example images of construction details of common houses. Successful pilot implementations of ACeBS in various regions of Indonesia demonstrate its potential as a valuable tool for DRR initiatives globally.

Learnings and Impact

ACeBS can now be effectively utilized for capacity development of communities and officials and also to conduct earthquake vulnerability assessments. However, certain challenges and a few suggested improvements which will help its future iterations are as follows:

- Prioritizing a systematic and widespread deployment of the application, for both public initiatives and professional assessments by independent institutions.
- Continuous application upgrades are also essential to keep up with evolving seismic knowledge and emerging technologies, which requires a dedicated development team.
- Capacity development initiatives are crucial as stakeholders, including national and local governments, need ongoing training to effectively use the app.
- Data storage and documentation presents a challenge, as the system must be able to collect and manage large volumes of assessment data while ensuring smooth accessibility. Regular system maintenance is necessary to fix bugs, optimize performance, and provide technical support to users, ensuring the app's reliability during critical times.

All the abovementioned challenges demand consistent investment, collaboration, and innovation to keep ACeBS as a reliable tool for disaster risk reduction in Indonesia. ACeBS has the potential to enable individuals to accurately determine the vulnerability of their homes and to establish a standardized measurement standard for all housing structures in Indonesia.

By fostering collaboration amongst various stakeholders, ACeBS can promote the construction of earthquake-resistant buildings. The current version of ACeBS can be upgraded into a professional version involving multiple stakeholders. This could help in building a national talent pool of building assessors and trainers. ACeBS can now be introduced across Indonesia, where millions of homes still need earthquake risk assessments. This would significantly improve national disaster preparedness. Earthquake-prone countries across the world could adopt the ACeBS model, promoting global cooperation in earthquake risk reduction and enhancing housing resilience worldwide.

E5: Enhancing Resilience of Infrastructure through Strengthened Governance

Bhutan Chile Madagascar Tonga

Submitted by:
United Nations Office for Disaster Risk Reduction (UNDRR)
and Coalition for Disaster Resilient Infrastructure (CDRI)

Introduction to the Initiative

The "Enhancing Resilience of Infrastructure through Strengthened Governance" initiative is being implemented in Bhutan, Chile, Madagascar, and Tonga. This initiative aims to help countries evaluate their infrastructure resilience, identify areas for improvement, and take appropriate actions. The approach includes legislative and regulatory reviews, stress testing to pinpoint system vulnerabilities and interdependencies, and evaluating existing resilient infrastructure practices using the Principles for Resilient Infrastructure.

The assessment creates a national roadmap for infrastructure resilience in each country. This pipeline of concrete interventions will make existing infrastructure systems more disaster-resilient, and future infrastructure planning and development disaster-proof.

Detailed Description of the Initiative

The Coalition for Disaster Resilient Infrastructure (CDRI) and the United Nations Office for Disaster Risk Reduction (UNDRR) are collaborating to enhance the resilience of infrastructure through strengthened governance in Bhutan, Chile, Madagascar and Tonga.

Developing robust and resilient infrastructure requires navigating multiple challenges. These include short-term thinking, untested assumptions, lack of local institutional capacity, inadequate policy and regulatory frameworks, and risk-blind investment. Additionally, there is a lack of understanding regarding what constitutes resilient infrastructure, as well as vulnerabilities, interdependencies and linkages between infrastructure assets and systems. Climate change and risk drivers such as urbanization and unsustainable investment decisions further exacerbate these challenges, emphasizing the need for more disaster-resilient infrastructure.

To address these challenges, CDRI and UNDRR developed an innovative approach for assessing infrastructure resilience in consultation with international partners and national experts. The Global Methodology for Infrastructure Resilience Review was launched during a COP28 Presidency Event on 6 December 2023. It consists of the following steps:

Map institutional governance and identify key stakeholders

This step includes identifying primary stakeholders from the energy, transport, ICT, water supply and waste management sectors. Stakeholders include government, regulators, operators, and owners, as well as those with cross-sectoral responsibilities. In addition, it also involves identifying financiers to facilitate infrastructure resilience.

Review existing policies and regulations

This step involves reviewing and aligning various cross-cutting and sectoral policies with reference to the Principles of Resilient Infrastructure developed by UNDRR.

Identify infrastructure vulnerabilities through a stress-testing analysis

The stress-testing analysis involves collecting data on infrastructure vulnerability and exposure, followed by a workshop with stakeholders and experts to assess the impact of various stressors. Data is collected in two broad categories: geographic information system (GIS) data and infrastructure performance data.

A practical application of GIS data is calculating the percentage of infrastructure assets in disaster-prone areas. Open data sources like the Global Infrastructure Resilience Index (GIRI), a core initiative of CDRI, can be used to compute this information. Additionally, parameters like outage frequency, infrastructure age, demographic changes, growth and energy transitions, coverage, and redundancy are used to collect information on infrastructure performance.

Experts score the vulnerability and exposure of critical infrastructure functions to selected hazards. A workshop with experts records their inputs along the following lines of action: (a) Identify critical infrastructure functions, (b) Identify key economic industries and score their relative importance, (c) Select and assess relevant hazards, and (d) Stress test the critical functions proposed by the UNDRR. This step highlights the infrastructure functions and hazards that are more relevant and should be addressed in more detail.

Assess current resilience through the Principles for Resilient Infrastructure

This step requires conducting a workshop with relevant stakeholders. representing all sectors. In this workshop, they are introduced to the Principles of Resilient Infrastructure, and through a group exercise the participants evaluate the level of implementation in the country. The step provides the analysis of the gaps in infrastructure resilience practices and identifies prioritization of actions

Develop an implementation plan and produce a final report

The implementation plan should use the key actions under the Principles for Resilient Infrastructure and outline the actions that a country can take to address the identified challenges and gaps. It should consider short-, medium- and long-term interventions for each sector, as well as cross-sectoral interventions.

The Enhancing Resilience of Infrastructure through Strengthened Governance project aims to integrate resilience into infrastructure planning, investment, and implementation. It assesses the infrastructure resilience of critical sectors like energy, ICT, transport, and water using a participatory approach to help stakeholders identify vulnerabilities and cascading impacts.

This initiative contributes to enhancing infrastructure resilience in the following ways:

- Improved understanding of infrastructure resilience and disaster risks among key infrastructure ministries and other actors (e.g., the project identifies vulnerabilities in the country's infrastructure systems).
- Strengthened capacity to conduct stress-testing of infrastructure systems and implement mechanisms to improve infrastructure resilience (e.g., a training component is included in the workshops)
- Enhanced coordination among key infrastructure stakeholders (e.g., new coordination mechanisms across sectors to better manage interdependencies)
- Concrete policy actions to strengthen infrastructure resilience, including:
  - Changes in decision-making within governments on project planning, selection, and procurement processes to give greater weight to resiliency considerations.
  - Reforms of government rules and regulations on infrastructure governance (e.g., requirements for infrastructure operators to undertake regular stress tests).
- A pipeline of priority actions and projects to address vulnerabilities during the project and a list of assets and sectors requiring a follow-up deep-dive review.

This project also contributes to reducing vulnerabilities among at-risk populations and addressing inequalities by assessing the impact of hazards and cascading risks on the most vulnerable communities, providing targeted recommendations to enhance infrastructure resilience and reduce the impact of hazards.

Launch of the Global Methodology for Infrastructure Resilience Reviews at COP28

ICDRI panel on Enhancing Resilience of Infrastructure through Strengthened Governance with Bhutan, Chile and Madagascar

Learnings and Impact

Some of the challenges faced during the project implementation in the four pilot countries included:

- **Logistical issues:** Coordinating country-level workshops required flexibility and adaptability, especially to best accommodate government officials' requests and needs. Language barriers necessitated translators and mobilized internal experts proficient in these languages.
- **Identifying local expertise:** Finding suitable local candidates was challenging in some locations due to the limited pool of experts. To overcome this, the project leveraged UN local networks and their presence on the ground.
- **Navigating changes in government:** Changes in government delayed implementation as new approvals were required. Building strong relationships and obtaining buy-in from multiple officials is crucial. Collaboration with local experts helped establish these relationships and support for the project.
- **National infrastructure assessments:** Findings highlighted the need for a deeper analysis of the water sector in some targeted countries. To address this, focused workshops were conducted with stakeholders from across the water sector for a more detailed analysis of the water sector resilience requirements in Bhutan and Tonga to test the approach.
- **Capacity building:** Capacity building was a critical component of the project. Government officials were keen to learn how to conduct stress testing and apply the resilient infrastructure scorecard. Separate training sessions were provided ahead of the workshops to equip officials with these skills, strengthening the project's sustainability, as governments are now able to independently perform stress testing and track progress using the scorecards.
- **Scalability and Regional Collaboration:** Other countries have expressed interest in implementing this infrastructure resilience assessment, and this project is scalable due to the development of the Global Methodology for Infrastructure Resilience Reviews. The countries involved (Bhutan, Chile, Madagascar and Tonga) are also able to share their insights and expertise with others in their regions interested in undertaking similar initiatives.

Additional Information

Readings

UNDRR and CDRI. (2023). Global Methodology for Infrastructure Resilience Review. https://cdri.world/upload/pages/1785232287906510_202312140503undrr_cdri_global_methodology_for_infrastructure_review.pdf

E6: Roadmap for Resilient Infrastructure in a Changing Climate, Ghana

Ghana

Submitted by:
United Nations Office for Project Services (UNOPS)

Introduction to the Initiative

The study led by Ghana's Ministry of Environment, Science, Technology, and Innovation (MESTI), in collaboration with Global Centre for Adaptation (GCA), University of Oxford, United Nations Office for Project Services (UNOPS), and United Nations Environment Programme (UNEP), quantified Ghana's climate adaptation needs in the energy, water, and transport sectors for the first time. GCA provided funding and technical review; University of Oxford provided a geospatial assessment of assets and hazards in the country to identify exposed assets and districts as well as to explore potential adaptation solutions (NISMOD); UNOPS provided project management services and led the enabling environment assessment; and UNEP collaborated and provided technical review.

The study supports the identification and prioritization of climate adaptation needs; showcases co-benefits of resilience investments; and provides a framework for actionable adaptation.

Detailed Description of the Initiative

Background

With climate change, Ghana is expected to experience acute climate hazards such as flooding and droughts, threatening its socio-economic development. Adapting to climate change in critical infrastructure sectors is crucial for Ghana's progress towards the SDGs, Paris Agreement and other development objectives.

The study quantifies Ghana's climate adaptation needs in the energy, water, and transport infrastructure sectors for the first time, supporting strategic planning and investment. Based on these needs, a prioritised 'roadmap' of 35 project concept options was identified across three main components of the infrastructure system: the built environment, the natural environment, and the enabling environment.

Methodology

The study, led by Ghana's Ministry of Environment, Science, Technology and Development (MESTI), benefited greatly from the expertise of a technical working group composed of experts and stakeholders across various professions, knowledge and practice communities. The study used state-of-the-art tools and methodologies, including:

- **National Infrastructure Systems Modelling Tool (NISMOD):** Developed by Infrastructure Transitions Research Consortium (ITRC), 60 partners from practice and led by University of Oxford, NISMOD is the world's first national infrastructure system-of-systems modelling platform and provides insights into infrastructure performance, risk and interdependencies.
- **Capacity Assessment Tool for Infrastructure (CAT-I)/EnABLE:** Developed by UNOPS, this is an assessment and prioritization tool to help governments facilitate sustainable, inclusive and resilient infrastructure development.
- **Sustainable Infrastructure Financing Tool (SIFT)/FundABLE:** This was developed by UNOP in collaboration with the University of Oxford to support a structured approach to identifying potential sources to finance an infrastructure project or national infrastructure pipeline. The tool can help bridge the gap between governments and infrastructure financiers to accelerate the implementation of infrastructure projects for sustainable, resilient and inclusive development.

At the core of these methods and tools was a systems approach to detailed infrastructure adaptation and planning. The methodology included:

- Quantifying infrastructure adaptation needs geospatially and at the asset scale.
- Evaluating adaptation investment and policy options exhaustively within the built, natural and enabling environments.
- Developing a roadmap of prioritized adaptation investment and policy options for meeting quantified needs and contributing to national development priorities (the SDGs, NDCs and gender impacts).
- Identifying potential sources of financing for identified adaptation options.

The approach allowed for a novel geospatial assessment of 156 nationally significant built and natural infrastructure assets such as power plants, dams, forest areas, roads, railways, etc. Four different hazard types were covered: flooding, drought, landslide, and reduced river runoff. Additionally, the assessment evaluated 11 areas of the enabling environment across the infrastructure lifecycle.

Adaptation Options and Roadmap

The roadmap consists of 35 projects focused on the built, natural and enabling environments. These adaptation options address specific gaps and vulnerabilities identified in the needs assessment, including:

- Protecting critical energy or water supply facilities and natural resources.
- Safeguarding critical transportation infrastructure.
- Supporting districts particularly vulnerable to climate impacts.
- Building institutional capacity aligned with existing government policies, plans and initiatives.

The roadmap provides information to attract potential financiers, including public, private and traditional sources. The assessment of Ghana's financing landscape through a strategic financing approach, including sources of finance, modalities and applicability in the context, revealed that Ghana has access to 82 infrastructure-related funds that to a varying extent can provide funding for projects in the built and natural environments. Of these funds, 71 percent provide funding for enabling environment activities and 62 percent provide project preparation financing necessary to engage private sector finance.

The roadmap aims to build infrastructure resilience by strengthening the built, natural and enabling environments. The 35 projects were prioritized based on their potential to address identified vulnerabilities and contribute to national development priorities. The roadmap also provides information on potential funding sources to support the implementation of these projects.

Ghana Technical Working Group Workshop

Learnings and Impact

Implementation challenges, mitigation measures and lessons learned

The data collection process was vital to this work and presented some challenges. A well-thought-out plan and strategy were essential for gathering and validating data, and strong coordination among stakeholders and government support played a crucial role in this endeavour. The study was conducted during the COVID-19 pandemic, which limited stakeholder availability. Therefore, data necessary for assessments were collected through online interviews instead of face-to-face consultations. Additionally, the reliance on older hazard datasets (from IPCC AR1) impacted the accuracy of the geospatial analysis performed. To validate key assumptions and ensure robust stakeholder engagement with the outputs, hybrid and online workshops were organized at various intervals to discuss preliminary findings, enhance the needs assessment, and validate proposed adaptation options. To further improve the project's impact, it was suggested that investments be made in higher-resolution hazard data.

Stakeholder engagement was fundamental to the success of the project. The government's active involvement, including the appointment of a Senior Technical Advisor, significantly enhanced the team's capacity and promoted collaboration among diverse stakeholders. This collaborative approach was effective in managing expectations, coordinating efforts, and fostering government ownership of the results.

Scalability and Replicability

The case of Ghana serves as a pioneering example of the use of multi-hazard risk assessment tools and data to integrate climate adaptation into national infrastructure planning and strategic financing.

Firstly, the study provides a detailed and prioritized actionable plan with 35 projects for addressing climate risks in Ghana's infrastructure sectors. The plan helps to highlight the co-benefits of resilience investments by addressing climate risks and promoting broader development objectives – SDGs, NDCs and gender equality – thus ensuring that resilience-building efforts contribute to multiple development objectives. The study also provides a practical framework for translating climate risk information into action by including project concept notes with justifications for investment with the identification of financing options for adaptation, thereby underscoring the practical utility of the roadmap.

Secondly, the study critically analyzes the financing landscape to reveal how Ghana has unexploited infrastructure-related funds. Financing options were defined in the roadmap, including where public and private sector resources can be mobilized alongside the finance from traditional sources. The assessment of Ghana's financing landscape reveals that the government of Ghana has access to 82 infrastructure-related funds, of which it has had existing relationships with 36 (44 percent) within the past 10 years. In total, 78 funds (95 percent) provide funding for projects in the built and natural environments, whereas 58 (71 percent) provide funding for enabling environment activities. Lastly, 51 funds (62 percent) were identified as being able to provide project preparation financing – an important area to develop full bankable project proposals – necessary to engage private sector finance in climate adaptation in the country. This becomes instrumental in mobilizing necessary resources and highlighting the criteria to be satisfied to maximize the probability of securing funds.

The study aimed to support the mobilization of finance for climate resilience in Ghana through engagement with financing partners after its conclusion. Project partners continue to work together to identify means of implementation for the adaptation options identified.

Additional Information

Readings

Ministry of Environment, Science, Technology & Innovation, Accra, Ghana, and UNOPS. (2022). Ghana: Roadmap for Resilient Infrastructure in a Changing Climate. https://content.unops.org/publications/Ghana-roadmap-web.pdf

E7: Vulnerability Study to Analyze the Effects of Climate Change on the Hydroelectric Sector, Côte d'Ivoire

Côte d'Ivoire

Submitted by:
Ministry for Europe and Foreign Affairs, Government of France

Introduction to the Initiative

The Agence Française de Développement (AFD) program "AdaptAction" is an ambitious study on the vulnerability of the hydroelectricity sub-sector in Côte d'Ivoire to climate change. The study aims to strengthen the resilience of populations and ecosystems and it included climate studies of the Sassandra and Bandama watersheds and the development of a forecasting and management tool. The challenges faced were multifaceted, encompassing technical, institutional, environmental and social aspects. On the technical front, the challenges pertained to models and tools development, improvement of hydroelectricity production, and dam and energy sector management. On the institutional front, the challenges related to forecasting collaboration among tool users. In the environmental and social realm, the challenges surrounded the impacts on water management, stakeholder mobilization and women's involvement. Nonetheless, this study presents Côte d'Ivoire with a significant opportunity to enhance hydroelectricity management and optimize production in the Sassandra and Bandama basins.

Detailed Description of the Initiative

The study focused on the hydroelectric sub-sector and other sectors utilizing water resources in the Sassandra and Bandama basins in Côte d'Ivoire. The already observed and expected impacts of climate change in Côte d'Ivoire have had adverse impacts on all sectors essential to the country's development, and more specifically on its water resources, which are closely linked to energy, agriculture and other sectors. The development of renewable hydroelectric assets, as well as the optimization of hydroelectric productivity and water resource management, especially in the context of climate change and growing tension over water, is crucial. This also calls for coordinated, effective and participatory responses from all stakeholders. This study was conducted by a consortium of companies comprising SUEZ Consulting, the engineering company Tractebel (which has an office in Côte d'Ivoire) and Acterra. The main beneficiaries CI-ENERGIES, CIE and SODEXAM were also the key stakeholders in conducting the study. This study, while collecting and utilizing data on existing climate scenarios for hydrological modelling of Bandama and Sassandra watersheds, aims to assess the potential impacts of climate change on the operation of infrastructure in the two basins.

Therefore, consultants used the Climate Resilience Guide for Hydro-Power Sector procedure (2019) recommended by the International Hydropower Association (IHA). The analysis included the following steps (i) definition of reference performance; (ii) initial climate analysis; (iii) climate resistance tests. A 30-year reference period (1989–2018) and two future horizons centred on 2040 (2025–2054, short-term) and 2080 (2065–2094, long-term) were selected for the climate analyses. Next, climate projections were analyzed throughout seven CORDEX-Africa models (GCM-RCM combinations) and two representative concentration pathway (RCP) scenarios: intermediate (RCP4.5) and pessimistic (RCP8.5).

For this study, precipitation, river flow and temperature were considered as stress factors for climate risk assessment. All models project a rise in temperature in the two basins, with the potential consequence of a loss of electricity transmission of 2.2% and 4.2% on average by 2040 and 2080 respectively. The majority of models (6 out of 7) predict an increase in mean annual precipitation, which would represent an opportunity for increased energy production in the future. However, the results also point to an increase in flood intensity in the future, with risks varying from one dam to another: low for the safety of the Kossou dam (Bandama basin), and high for the Buyo dam (Sassandra basin).

Based on the results, multiple adaptation measures were identified in a participatory approach, according to the level of flood risk at different horizons in each basin, and also taking into account the specific realities of each dam to strengthen the system's resilience to climate change. For example, to ensure robustness at Tiassalé (Bandama basin) with the high risk of flooding, it is recommended to increase the spillway capacity of the facility. With regard to safety at Bouyo (Sassandra basin), the recommended measure is the construction of an upstream reservoir. With regard to energy production, the installation of an alternative energy source, such as solar power, will be necessary to supplement the hydroelectric sector in future drier climates. Subsequently a monitoring plan was developed to ensure that adaptation measures, wherever necessary, are carried out in a timely manner. A management tool has also been developed to model the operation of hydroelectric systems in Sassandra and Bandama watersheds over several future scenarios.

In addition to infrastructure resilience, the tools and recommendations call for an integrated management of water resources amongst different stakeholders in the context of climate change. This will further strengthen the resilience of other users, such as that of the local populations for consumption, farmers for production, and livestock breeders for their herds

Learnings and Impact

The main challenge under the study pertained to timely data accessibility and data quality. To remedy this, the hired consultants proactively worked on the model using their own database (TRACTEBEL database) and publicly available spatial data online (CHIRPS, a 35+ year quasi-global rainfall data set).

Additionally, it was observed that consultation among water resource users varies. While there is communication between the hydroelectric sector and the drinking water supply sector, there is no consultation with agricultural users. These findings have informed the set of recommendations supplemented by a monitoring and governance plan.

The management tool is simple and tailored to the needs and capabilities of its users. It also allows for for easy integration of new input data or developments in the basins.

Additional Information

Video Link

AFD. (2022). Changements climatiques et hydro-électricité en Côte d'Ivoire. YouTube.
https://www.youtube.com/watch?v=XmaYv_-wb1M

E8: Climate-Resilient Infrastructure Stress Testing, Bangladesh

Bangladesh

Submitted by:

Ministry of Infrastructure and Water Management, Government of the Netherlands

Introduction to the Initiative

This case study explores the implementation of the Climate-Resilient Infrastructure Stress Test for Bangladesh. Led by Bangladesh's Ministry of Environment, Forest and Climate Change (MOEFCC), the assessment brought together expertise via the Global Center on Adaptation (GCA) and the United Nations Office for Project Services (UNOPS), with technical analyses undertaken by the University of Oxford and the Center for Environmental and Geographic Information Services (CEGIS) in Bangladesh, and support from the Ministry of Infrastructure and Water Management of the Netherlands. With the aim of evaluating climate risks to infrastructure and of prioritizing adaptation investments, the project is a pioneering effort to use advanced climate models and geospatial data to safeguard critical infrastructure in one of the world's most climate-vulnerable nations. By identifying and mitigating risks to key sectors, the initiative has demonstrated how to strengthen resilience through a systematic and data-driven approach for pre-identifying potential points of concern within the infrastructure domain, thus informing advance action that can protect millions of lives and livelihoods and critical assets.

Detailed Description of the Initiative

The initiative covers the transport and energy sectors and social infrastructure such as healthcare facilities, educational institutions, cyclone shelters, and market centres, which are critical for maintaining economic and social stability.

Bangladesh, with its coastal and low-lying geography, is highly vulnerable to extreme climate events, including cyclones, floods, and rising sea levels. The existing infrastructure in this region is at high risk of failure, threatening lives and economic productivity. In response, the Global Center on Adaptation (GCA) partnered with the government of Bangladesh to implement the Climate-Resilient Infrastructure Stress Test. This test aimed to assess the resilience of key infrastructure systems, identify risks, and develop prioritized investment strategies for adaptation.

Implementation

The initiative used a comprehensive stress-testing framework, drawing on best practices from previous implementations in the Netherlands and Ghana. It involved the following steps:

- **Identifying and mapping physical climate hazards:** This included considering current and future climate scenarios (RCP 4.5 and 8.5) and using both high-resolution (50–100m grid) and low-resolution (>20–50km) datasets.
- **Identifying hotspots based on infrastructure asset exposure:** This involved intersecting climate hazard data with geospatial mapping of assets and networks to pinpoint areas most vulnerable to climate-induced risks.
- **Assessing the direct impact of climate hazards on critical infrastructure:** Well-established depth damage functions were used to evaluate potential damage for present and future climate scenarios.
- **Quantifying the effects of service disruptions on household welfare:** This step utilized relevant datasets, including household data from the World Bank, to develop a spatial proxy of household welfare and infrastructure access in the coastal zone. This analysis led to the development of household-level risk profiles.
- **Assessing the negative impact of household service disruptions on progress towards the Sustainable Development Goals (SDGs):** This involved stakeholder consultations and analysis of key national documents.

The process was based on advanced data on climate hazards including floods, coastal erosion, extreme heat, and cyclonic winds, that was collected from national meteorological agencies and global databases. Infrastructure data, including the location, capacity, and vulnerability of roads, bridges, power plants, and schools, was overlaid on climate risk maps. Vulnerabilities were identified based on exposure to various climate hazards such as coastal flooding, riverine flooding, cyclonic winds, and erosion. This helped to identify "hotspots" where critical infrastructure was most at risk from future climate scenarios (2030–2050).

This initiative holds the potential of significant positive impact on Bangladesh's disaster resilience, with the following thrust areas:

- The stress-testing process provided government agencies with crucial information on infrastructure vulnerabilities. This enables them to focus resources on upgrading and maintaining assets most at risk from climate impacts.
- The integration of social infrastructure, such as schools and hospitals, into the planning process has ensured that critical services remain operational during disasters, benefiting local populations.
- By conducting community consultations, the project has promoted a participatory approach, incorporating local knowledge and priorities into the final investment strategies.

Learnings and Impact

Challenges and Mitigation

One of the major challenges during implementation was the lack of high-resolution local data, particularly in rural coastal areas. To mitigate this, the project team partnered with local universities and research institutes to gather real-time data and improve the accuracy of hazard assessments. In addition, gaps in institutional capacity required GCA to conduct several training sessions for government officials on using climate risk tools and stress-testing methodologies.

Scalability

The Stress Test pilot project in Bangladesh serves as a model for other coastal countries facing similar climate risks. The methodologies and tools developed are adaptable to other regions, with the potential to scale up across South Asia.

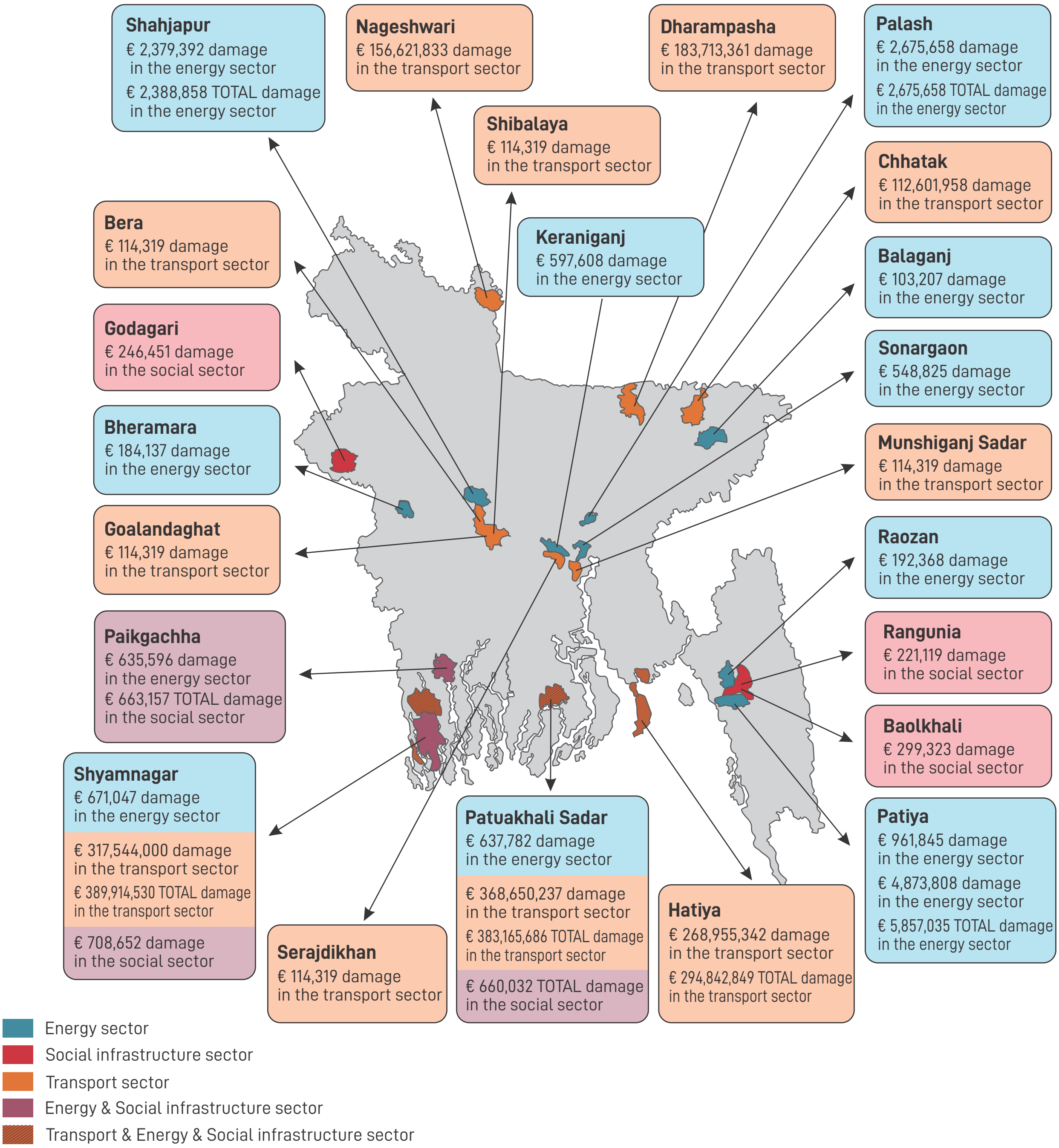
Co-benefits

The project generated significant co-benefits, including enhanced institutional coordination across government ministries and the creation of a robust database on climate and infrastructure risks. It also increased public awareness of climate risks, helping coastal communities to advocate for more resilient infrastructure investments.

Way Forward

Overall, the findings from this assessment can help target and prioritize adaptation investment options to enhance the resilience of infrastructure and livelihoods of vulnerable populations. In addition to the technical advances provided in this study through high-resolution, multi-hazard and societal welfare assessments, analyses of the enabling environment, through continuous consultations with local stakeholders, have ensured that the technical work is relevant for the current policy and planning landscape in Bangladesh. Future work will focus on implementing the prioritized adaptation investments and developing a long-term financing strategy. Continued collaboration with international financial institutions will ensure sustained investment in infrastructure resilience. Additionally, GCA plans to expand stress testing to include nature-based solutions, such as mangrove restoration, to complement the hard infrastructure upgrades.

Figure E8.1: Summary map highlighting the key sub-districts of Bangladesh that experience the greatest exposure and direct economic damage to infrastructure assets



Additional Information

Readings

Gall, S.S., Adnan, M.S.G., Peard, A., Paszkowski, A., Adshead, D., Cançado, D., Diaz, S., Saha, C.R., Jain, N., Istiaque, T., Hall, J.W., Haque, S., Kohler, S., and Rector, I. (2022). Bangladesh: Climate-resilient infrastructure assessment. University of Oxford, United Nations Office for Project Services (UNOPS), Center for Environmental and Geographic Information Systems (CEGIS), and the Global Center on Adaptation (GCA).

E9: Climate Change Adaptation in Coastal Ports, Brazil

Brazil

Submitted by:
Ministry of Ports and Airports, Government of Brazil

Introduction to the Initiative

This initiative assesses the impacts and risks of climate change on 21 public coastal ports in Brazil. It was implemented by WayCarbon in collaboration with the Brazilian National Waterway Transportation Agency (ANTAQ), the National Institute for Space Research (INPE), and the German Development Cooperation (GIZ). The study aimed to develop a Climate Risk Index and recommend adaptation measures to minimise risks related to sea level rise, storms and strong winds. This project contributes directly to reducing climate vulnerabilities in Brazil's maritime sector, which is critical for the nation's economy.

Detailed Description of the Initiative

The project focuses on the transportation and infrastructure sector, particularly Brazilian coastal public ports, which handle about 90 percent of the country's foreign trade. These ports are highly susceptible to climate risks like sea level rise, storms, and strong winds due to their geographical positioning and proximity to the coast. The study was initiated to assess these vulnerabilities and identify appropriate adaptation strategies to secure the country's trade and economic stability.

Implementation

The project began in January 2020 through a partnership between ANTAQ, GIZ, and WayCarbon, supported by INPE. It involved a detailed climate risk assessment using the Intergovernmental Panel on Climate Change (IPCC) framework, combined with extensive stakeholder consultations, workshops and data collection from port authorities.

Use of RCP Scenarios and Steps Followed

To assess the future climate risks, the study utilized Representative Concentration Pathway (RCP) scenarios, specifically RCP 4.5 (moderate emissions) and RCP 8.5 (high emissions). These scenarios project possible greenhouse gas concentration trajectories and their impact on climate hazards such as sea level rise, storms, and strong winds. The analysis was carried out for two time horizons: 2030 and 2050, to understand how these hazards might evolve over time.

The following key steps were undertaken during the study:

- **Review of Methods:** The team conducted a comprehensive literature review of global climate risk methodologies, with a particular focus on port infrastructure. The IPCC framework was validated for the Brazilian context with minor adjustments to account for data limitations.
- **Assessment of Impacts:** A detailed electronic survey was conducted among 21 public ports to collect data on the impact of climate hazards. Port authorities provided insights into operational challenges posed by thunderstorms, strong winds and other extreme weather events.
- **Climate Hazard Analysis and Scenario Definition:** Climate hazards were analysed based on the RCP 4.5 and RCP 8.5 scenarios. Key hazards – sea level rise, storms and strong winds – were selected due to their high potential to disrupt port operations. INPE's technical expertise played a crucial role in modelling these scenarios and generating hazard projections for future periods.

- **Vulnerability and Exposure Assessment:** Data from the surveys and relevant literature were used to determine vulnerability and exposure levels for each port. A comprehensive Climate Risk Index was then calculated, considering both the current situation and future projections based on the RCP scenarios.
- **Risk Assessment:** Using the RCP scenarios, ports were ranked based on their exposure to projected hazards, resulting in a prioritised list of the most at-risk locations. Ports like Aratu-Candeias, Cabedelo, and Rio Grande were identified as particularly vulnerable.
- **Adaptation Measures:** Fifty-five adaptation measures were identified, including both structural and non-structural strategies. These were tailored to address the specific risks identified for each port, with a focus on infrastructure reinforcement and environmental resilience.

Learnings and Impact

Impact

The project revealed critical climate risks, particularly for ports like Aratu-Candeias, Rio Grande and Cabedelo. The recommended adaptation measures, such as infrastructure upgrades and enhanced drainage systems, aim to protect these ports from future climate impacts. This initiative strengthens the resilience of Brazil's port infrastructure, ensuring the continued flow of trade and minimising economic disruptions.

Challenges and Mitigation Strategies

The primary challenge was the limited availability of climate data specific to ports, which was mitigated by leveraging INPE's advanced climate modelling capabilities. Additionally, some ports lacked adequate weather monitoring systems, highlighting the need for further investment in meteorological infrastructure.

Scalability

This initiative is highly scalable, both within Brazil and internationally. Ports around the world face similar risks from climate change, and the methodology used in this study can be applied to assess vulnerabilities and develop adaptation strategies for other regions.

Co-benefits

Beyond improving port resilience, the project enhances economic stability by safeguarding trade routes. It also indirectly benefits coastal communities that rely on the efficient operation of ports for their livelihoods.

This case study offers a robust framework for protecting coastal trade infrastructure against the growing risks of climate change. By utilising RCP scenarios and a comprehensive Climate Risk Index, it provides a replicable model for other countries to follow in their efforts to safeguard vital infrastructure.

E10: Building a Resilience Strategy for Transport Infrastructure, France

France

Submitted by:
Ministry for the Ecological Transition, Government of France

Introduction to the Initiative

This work proposes a 10-step methodology for building a resilience strategy for transport infrastructure in France to deal with climate-related hazards. In the context of climate change, this work aims to assess the interface of climate risks and transport infrastructure through an analytical framework that focuses on vulnerabilities and criticalities of transport infrastructure to current and future climate scenarios. Further to the risk analysis, the methodology helps in the identification of adaptation measures and prioritizes those to implement an effective adaptation strategy.

Detailed Description of the Initiative

The method of building a resilience strategy requires defining the objectives, scope, and governance of the approach. By developing an adaptation strategy, road authorities, asset and network owners can pursue various objectives related to optimising their budgets and investments. This would, in turn, help in network maintenance, ensuring a certain level of service provisioning.

The objectives setting phase guides the overall scope of the analysis, categorized within the following identifiers:

- The climatic scope, i.e., the hazards to be assessed; the horizons and scenarios of projection
- The physical scope, which corresponds to the different infrastructures to be assessed
- The functional scope, which is the list of services or functionalities (commuting, goods transport, etc.) provided by a network, and
- The geographical scope, which depends on the three previously mentioned scopes.

The following are the key steps involved in building a resilient strategy for transport infrastructure:

- Facilitating vulnerability assessment by carefully choosing and categorizing the transport assets.
- Identifying and gathering asset data, data related to their functionalities, and climatic data (past, present and projected). This step is highly dependent on the defined scopes.
- Analyzing the climate projections based on long-term hazard data, such as its severity or frequency.
- Rating the infrastructure sensitivity to hazards. The sensitivity rating may increase depending on the inherent characteristics of the infrastructure, such as its age, its level of maintenance, its construction material, and the standards used for its design or construction.
- Assessing the physical vulnerability of networks, systems and components by cross-examining the sensitivity of the infrastructure due to its exposure to climate hazards.
- Defining and rating the functional vulnerability of the network due to hazards, which corresponds to the level of impact on their functionalities, such as whether a disaster-affected road would be inoperable for one or more hours, ultimately leading to traffic slowdown.

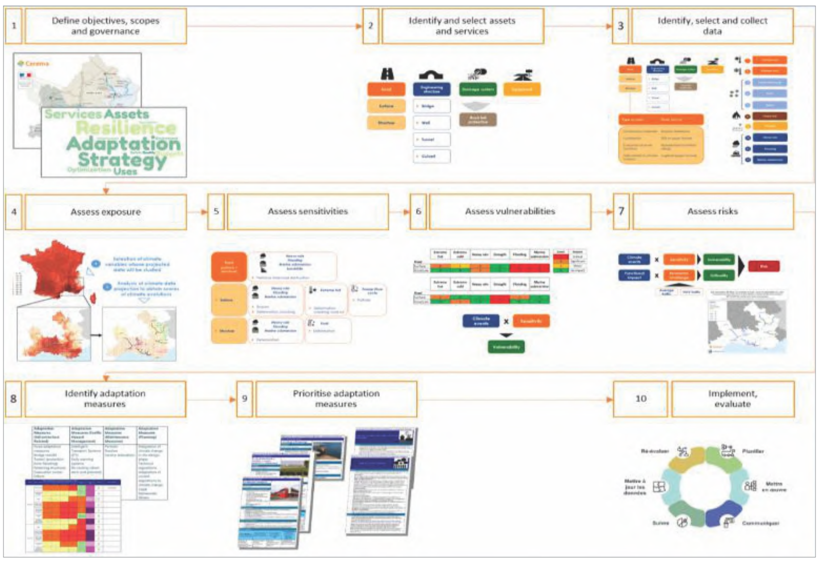
- Assessing risks requires defining the services provided by a transport network to a territory or the territory's expectations from the network. The risk analysis consists of identifying the impact of climate hazards on these services or expectations. This step is different from the functional vulnerability assessment, which does not consider the issues related to serving the territory.
- Identifying adaptation measures for assets at risk. Adaptation options may relate to the exposure of assets, their sensitivity, vulnerabilities or risk. Various adaptation solutions exist related to the design, construction, maintenance, exploitation and planning of infrastructure leading to hazard mitigation.
- Defining a resilience strategy by prioritizing the previously identified adaptation options. This is aligned to meet the objectives defined in the first step, and it will generally include recommendations on the adaptation measures to be adopted. It is designed to be embedded in the relevant decision-making processes.
- Implementing the resilience strategy and creating mechanisms for its regular monitoring.

Learnings and Impact

This method has been applied, fully or partially, in France to many transport infrastructures, notably the rail networks (SNCF Réseau: Axe Seine, the new LGV-line Montpellier-Perpignan, Bordeaux-Toulouse axis of the Grand Projet du Sud-Ouest, which is a new LGV line, Occitan network; LGV SudEurope Atlantique for the operator Lisea), road networks (Nièvre department, a section on Highway 9 for the operator ASF, the network operated by Sanef/SAPN) and ports (Grand Port Maritime de Bordeaux, Port Atlantique de La Rochelle, Grand Port Maritime de la Martinique).

- A vulnerability study is currently planned for 2023–2024 on the 21,000 km of the French national road network (including the concessionary motorway network).
- This method is also currently being applied in a large multi-modal risk assessment of the transport infrastructure of the Sud-PACA region.

Figure E.10.1: Main steps of the methodology to build a resilience strategy



Source: Ministry for the Ecological Transition, Government of France

F Strengthening Governance for Infrastructure Resilience

F: Strengthening Governance for Infrastructure Resilience

Institutional governance, including robust codes and standards, resilience policies and frameworks, and risk-informed decision-making processes, is vital for ensuring infrastructure resilience. This section comprises 12 case studies that collectively demonstrate that a comprehensive governance strategy, supported by risk assessments, strong regulations, and inclusive stakeholder engagement, is key to safeguarding infrastructure and reducing vulnerabilities to future disasters.

Several countries have made significant strides in institutionalizing resilience within national frameworks. Costa Rica's adoption of UNDRR's Principles for Resilient Infrastructure and Bhutan's policy and legislative reforms to strengthen its built environment illustrate the importance of integrating resilience into national laws. Bhutan's Construction Quality Compliance Mechanism (CQCM) regulates construction projects, ensuring adherence to building codes designed for resilience. Similarly, the UAE's National Emergency Crisis and Disaster Management Authority (NCEMA) sets a phased framework for safeguarding National Critical Infrastructure (NCI) through continuous improvement and future-readiness. These cases demonstrate the need for resilient governance at the national level to ensure long- term infrastructure stability.

The case study from the European Union on European standards and codes helps understand how these codes have a key role in achieving a climate-neutral, resilient and circular economy by providing common technical rules for the design and renovation of buildings and other civil engineering works.

Portugal's Wildfire Resilience Standards for Buildings focus on fire-resistant construction in wildfire-prone areas, ensuring that homes and public infrastructure are protected from recurring wildfires. In Italy, the National Seismic Prevention Plan (NSPP) focusses on retrofitting buildings to withstand earthquakes.

The case study from Japan is an example of how an agile and dynamic government National Resilience Policy Framework can help ensure better against worst-case disaster scenarios such as tsunamis and major earthquakes.

Robust risk assessments and data-driven governance frameworks are key to enhancing infrastructure resilience. The Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol implemented in Lesotho supported risk- informed decision-making and resulted in national policy, regulatory, organizational and procedural improvements for addressing vulnerabilities of the water supply system. In Japan, continuous vulnerability assessments under its Basic Act on National Resilience informed updates to its national resilience plan, ensuring infrastructure is adapted to address emerging risks.

Governance efforts must also engage the private sector to ensure widespread adoption of resilient practices. The case study from UAE, on Business Continuity Management System (BCM), aligned with NCEMA7000:2021 standards, ensures the continuity of vital services like telecommunications during crises. Private sector cooperation was key to aligning critical infrastructure with national resilience goals. Similarly, the case study from Australia on the Resilience Ratings System is an example of incentivizing private property owners to upgrade buildings to meet resilience criteria by offering financial incentives such as reduced insurance premiums. These initiatives illustrate how regulatory frameworks can effectively engage private stakeholders to enhance overall resilience.

Governance frameworks that promote collaboration between government entities, private sector participants, and communities are essential for infrastructure resilience. Japan's national resilience plans also incorporate regional input, ensuring that local authorities play a significant role in national planning. These initiatives show the importance of collaborative governance, where stakeholders across all levels of society contribute to building and maintaining resilient infrastructure.

Key Takeaways

- Governance mechanisms informed by data and robust risk assessments are key to enhancing decision-making for infrastructure resilience.
- Hazard-specific regulations underscore the need for tailored solutions to address unique geographical vulnerabilities.
- The involvement of government agencies, private sector partners, and local communities fosters a shared sense of ownership and promotes long-term resilience, helps bridge gaps in capacity and ensures widespread adoption of resilient practices.
- Regulatory frameworks need to effectively engage private stakeholders to enhance overall resilience.

F1: Standards for Wildfire Resilience of Buildings, Portugal

Portugal

Submitted by:
National Authority for Emergency and Civil Protection, Government of Portugal

Introduction to the Initiative

Portugal is a country prone to wildfires. According to the National Risk Assessment, wildfires pose an extreme risk in the country due to their high probability and impact. The year 2017 was the most critical on record, with fires causing over 100 fatalities and burning 500,000 hectares. In addition, hundreds of buildings were affected, including houses and industries, and other economic activities severely affected. In response to the 2017 disaster, the Portuguese government implemented a regulation establishing fire resistance requirements for buildings.

Detailed Description of the Initiative

Rural fires occur annually on the Portuguese mainland, especially during the summer. These fires have a significant impact on the local communities and the country as a whole. In Portugal, the mountainous areas of the North, Centre, and Algarve have the highest risk of rural fire. Villages, housing settlements, road and rail infrastructure, and sections of the electricity grid are located in these high-risk areas.

Climate scenarios indicate an increased risk of rural fires due to changes in the thermal climate (a greater number of hot days and heat waves) and due to the reduction in water availability (increasing trend of dry periods). This makes rural areas more vulnerable to fires, which may occur with greater frequency and intensity, putting human lives at risk. Strengthening the structural resistance of buildings and other infrastructure in the most dangerous areas, especially in the urban-wild interface, is crucial.

In response to the dramatic consequences of the 2017 fires, the Portuguese government issued a legal regulation (Order No. 8591/2022, of 13 July 2022) establishing specific requirements to enhance the fire resistance of buildings to a possible fire impact. Under the umbrella of the Portuguese Integrated Rural Fire Management System, building owners already had the obligation to clear vegetation within a 50-meter radius of their buildings to reduce fire propagation.

The fire vulnerability of buildings at the settlement-forest interface is largely due to the fire reaction and resistance characteristics of the construction materials used on its external and internal parts, as well as architectural characteristics and details and openings or weak points in the building envelope. The new regulation goes even further by establishing measures to ensure that the building construction elements reduce the impacts of fire. It considered the performance of the building's construction elements and materials in relation to exposure to rural fires, focussing on the fire resistance of the structural elements, roofs, external wall coverings, doors, windows and skylights.

Since 2022, new buildings constructed in a high or very high wildfire risk area must fulfil these new standards. This regulation significantly improves Portugal's resilience and preparedness levels towards critical risk in vulnerable areas, with the potential to generate concrete results.

In basic terms, this new regulation introduced more demanding requirements in terms of the construction material's resistance to fire as compared to the regular fire safety standards. This means that if the new building is located in a zone with a high or very high wildfire risk, the law will demand a higher level of fire resistance so that it can withstand the impacts of a fire for a longer period of time.

The table below showcases the fire resistance rating proposed for residential buildings (Use-type I) under different risk categories (depending on the building's size, occupancy, and other factors) in an area with medium exposure to wildfires.

Table F1: Fire Resistance Ratings for Wildfire Resilience in Portugal

Use-type (UT)	Risk Category (CR)	Fire Resistance Rating (R/REI)
Residential (I)	1st	R60 REI60
Residential (I)	2nd	R60 REI60
Residential (I)	3rd	R90 REI90
Residential (I)	4th	R120 REI120

Note:
Use-Type (UT): The primary function of the building (e.g., residential, commercial, industrial).
Risk Category (CR): The overall risk level of the building, considering factors like occupancy and the presence of hazardous materials (1st category means lower risk; 4th category means higher risk).
R: refers to the resistance of the element to the passage of heat.
REI: Includes resistance to heat, integrity (preventing the passage of flames), and insulation (preventing the temperature on the unexposed face from rising excessively).
Numbers after R or REI: Indicates the number of minutes the element must withstand the specified fire conditions. For example, R60 means the element must resist the passage of heat for 60 minutes.

The level of resistance depends on the function of the building and the exposure to wildfire. For example, if a building is classified as an industrial building (Use-Type XII) with an "Extreme" Rural Fire Exposure Class, the structural elements must resist the passage of heat and flames for a longer period of time as compared to values shown in the previous table. For example, in the 4th Risk Category, buildings must have a fire resistance rating of R240 and REI240.

The regulation also contributes to Target C of the Sendai Framework for Disaster Risk Reduction ("Reduce direct disaster economic loss in relation to global gross domestic product"), specifically in the economic sector and productive assets (Target C-3) and the housing sector (Target C-4).

Learnings and Impact

It is still too early to fully access the direct impact of the regulations, as they have been in force for only two years. However, the legislation unexpectedly had a positive impact: as citizens became aware of the new building regulations applied in certain areas, they also became more aware of the wildfire risk in those locations. On the other hand, one challenge already seen on the ground was that installing materials with higher fire resistance increases the cost of buildings.

To further improve this initiative, some refinement could be considered in order to have more precise requirements for each type of building. Currently, the standards are the same for residential buildings, hospitals, schools, and hotels; in the future, differentiation between these types of buildings might be introduced. Other adjustments could be to include specific measures targeting infrastructure that provide vital services.

Additional Information

Readings

Autoridade Nacional de Emergência e Proteção Civil. (2022). Despacho n.o 8591/2022. In Diário Da República: Vol. 2.a série (pp. 67–69). (Portuguese) https://files.diariodarepublica.pt/2s/2022/07/134000000/0006700072.pdf

Supporting document (Portuguese version). https://prociv.gov.pt/media/fnjob2ui/doc-enquadrador.pdf

F2: SiLK – Guidelines for the Protection of Cultural Property, Germany

Germany

Submitted by:
German Federal Foreign Office, Government of Germany

Introduction to the Initiative

The SiLK guidelines[21] were developed by the German Conference of National Cultural Institutions (Konferenz Nationaler Kultureinrichtungen/KNK). The guidelines cover a total of 14 topics and comprise introductory information, questionnaires and a knowledge base to raise awareness on issues surrounding the protection and conservation of cultural property in museums, libraries and archives. These include general security management and protection against other hazards such as fire, flood, theft, vandalism, accidents/malfunctions, deterioration/wear and tear, climate, light, pests/mold, pollutants, severe weather, earthquakes and violence.

The SiLK guidelines (the acronym stems from the initial letters of the German title Sicherheits Leitfaden Kulturgut/SiLK guidelines for the protection of cultural property) are available in German, English and Arabic. The project is currently being funded by the Federal Government Commissioner for Culture and the Media.

Detailed Description of the Initiative

The SiLK project was initiated in 2006 after two devastating disasters hit institutions of the KNK: the fire in the Duchess Anna Amalia Library of The Klassik Stiftung Weimar in 2004 and the flooding of the Elbe river in 2002, which threatened several outstanding cultural heritage sites and art collections in Dresden. After these events, since 2005, the KNK has devoted itself to implementing security and disaster protection protocols for museums, archives and libraries. In October 2006, the KNK hosted an international conference on the topic. The participants discussed numerous aspects, including formal and legal requirements, disaster protection policies and preventive conservation measures. At the conference, the participating institutions expressed a need for more detailed information. The response was the creation of an online database which serves as a comprehensive reference work and resource for information on all matters related to safeguarding the cultural assets in museums, libraries and archives.

The SiLK guidelines comprise introductory information, questionnaires and a knowledge base which together raise awareness about issues surrounding the protection and conservation of cultural property in museums, libraries and archives. The guidelines help staff evaluate the protection efforts of their own institution, and offer suggestions and possible solutions (documents and links referred to are in most cases only available in German). They also include a wide range of information of interest to others in the field. Each topic has an associated introduction, questionnaire and knowledge base, with the questionnaire forming the core element. After answering all the questions, users obtain a "traffic light assessment": if the minimum standard is not reached ("Red") or if an ongoing threat exists ("Amber"), the assessment will include recommendations for action or mitigation measures. The knowledge base contains further information on each topic, such as lists of specialist publications, applicable guidelines and standards, examples and reference materials (e.g., emergency plans), and definitions and links (in German). Thus, using SiLK guidelines, cultural institutions can evaluate the potential risks for their collections and obtain guidance.

[21] SILK - SicherheitsLeitfaden Kulturgut. (n.d.). https://www.silk-tool.de/en/

The project is currently being funded by the Federal Government Commissioner for Culture and the Media. The translation of the German SiLK version into English was made possible by the German Insurance Association (GDV). The Arabic-language version was realized by the German Archaeological Institute/ArcHerNet with funding from the Federal Foreign Office.

Development and revision of SiLK

The SiLK project was founded and is still managed by the architect Almut Siegel and the social anthropologist Alke Dohrmann, both specialists in cultural property protection. To complete the chapters on specific topics, the project managers established a team of experts consisting of one or two specialists for each topic, including scientists, engineers, conservators, and other cultural heritage specialists. Among them are specialists in various fields such as lighting experts, fire protection officers, criminologists, engineers in technical building equipment, security specialists, entomologists (for the chapter on pests/mould), building physicists, and former military experts from the German armed forces. The texts and questionnaires were put online in 2012 (with the first half already available in 2010). During the development process, the specialists were responsible for proposing the content of each chapter, while the SiLK team assisted with editing, choosing details, and held overall editorial responsibility. All texts were discussed and tested in interdisciplinary workshops to ensure they were correct and comprehensive. The aim was to make all SiLK information easily accessible, even for non-experts in the field.

Relaunch in 2021

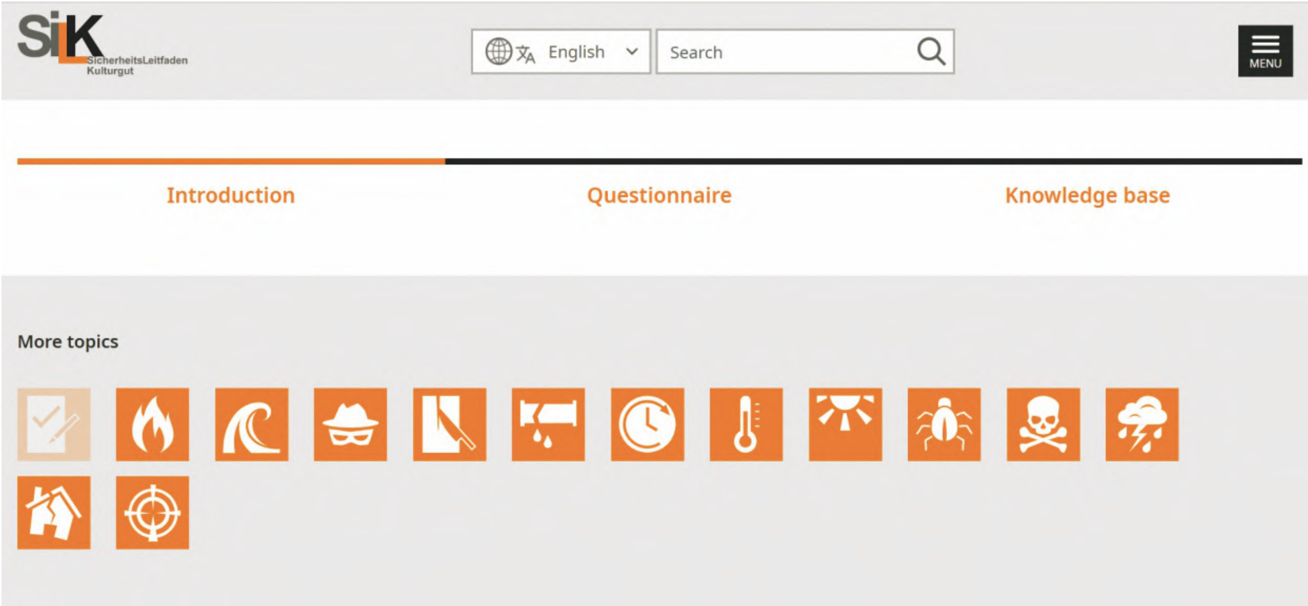
In 2021, SiLK was completely revised and relaunched in a new and more clearly recognizable design. Now each chapter is symbolised by its own easily recognizable icon and colour scheme that guides users through the different parts of the website. Furthermore, all texts have been carefully reviewed and updated to reflect the latest scientific knowledge and new technical standards. The SiLK platform is managed and continuously updated to meet the latest standards and knowledge by "SiLK GbR", led by Almut Siegel and Alke Dohrmann.

Learnings and Impact

Application of SiLK

The SiLK Tool is well known in German-speaking countries and is used by many cultural institutions, associations, administration units, public and representative bodies, while the user group is still growing. In 2023 the SiLK website counted almost 22,000 views, while the first half of 2024 shows almost 18,000. The most frequently visited page is the one on general security management. SiLK is most frequently used in Germany, followed by Saudi Arabia, Algeria, Morocco, Syria, Iraq, Jordan, Turkey and Libya. SiLK is not only used for evaluating collections but also serves to facilitate planning processes and support teaching and research activities. For instance, the new building for the Historical Archive of the City of Cologne, which was constructed to replace the former building that collapsed in 2009, was planned with the help and information provided by the SiLK Tool.

SiLK is free of charge and accessible anonymously for everybody without registration, ensuring that no sensitive user data can be lost or misused. SiLK addresses all kinds of cultural institutions regardless of collection type, size, organizational structure and all professionals as well as any interested individual. The main target group are small and middle-sized museums, archives and libraries without any specialized personnel in the field. The guidelines are easy to use and accessible to everybody regardless of prior knowledge. To achieve this aim, SiLK offers information at all professional levels. Untrained personnel can get necessary basic information by reading the introductory texts, while experienced users and specialists may find further information in the knowledge base. Thus, the SiLK Tool is an instrument for self-help for anyone interested in or entrusted with cultural heritage protection matters.



A snippet from the SiLK webpage

Additional Information

Readings

SILK - SicherheitsLeitfaden Kulturgut. (n.d.). English version. https://www.silk-tool.de/en/

F3: Protecting Public Investments for Resilient and Sustainable Water Supply to Advance Risk-Informed Development, Lesotho

Lesotho/SADC

Submitted by:
German Federal Foreign Office, Government of Germany

Introduction to the Initiative

In Lesotho, the Global Initiative on Disaster Risk Management (GIDRM) and its partners implemented the first vulnerability assessment using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol that was developed in Southern Africa. The Metolong Dam Water Supply System in Lesotho was assessed to better understand the service reliability of this critical infrastructure system under changing climatic conditions and identify potential consequences of varying water service levels for key user groups. The assessment was undertaken alongside a conceptual framework "Enabling Environment for Risk Informed Development" (EE4RID), describing a set of policy, regulatory, organizational, procedural, and cultural conditions needed to institutionalize risk-informed approaches within development decision-making.

Detailed Description of the Initiative

Water is critical for a nation's social and economic functions. In the Southern African Development Community (SADC) region, climate change-related water shortages pose a systemic risk with severe potential negative consequences. Water scarcity can cascade into crises across various sectors, including energy, agriculture, health and the economy as a whole. This can potentially lead to involuntary migration flows as well as political and social instability. Therefore, managing critical water infrastructure from a systemic, transboundary and risk-informed perspective is essential for resilient and sustained water provisioning, and key for advancing risk-informed development (RID).

RID describes a paradigm shift – across sectors and stakeholders – from managing single hazards to incorporating multiple existing and future risks into all development processes. It involves choosing development pathways that prevent the creation of new risks. This is a continuous process of addressing complexity for a more sustainable and resilient future.

Lesotho: The Water Tower of Southern Africa

Lesotho, known as the "water tower" of Southern Africa, plays a crucial role. Water-related development decisions here have an immediate impact on SADC countries downstream. Recognizing this, GIDRM, commissioned by the Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the German Development Cooperation (GIZ), piloted a systemic risk assessment process to advance climate resilience of Lesotho's critical water infrastructure, investments and services. The assessment was undertaken in cooperation with Climate Risk Institute from Canada, which, together with GIZ and the Institute of Catastrophic Loss Reduction (ICLR), forms the PIEVC Program Alliance.

The project focused on Metolong Dam Water Supply System to understand its reliability under changing climatic conditions and determine the possible consequences of water supply fluctuations for critical user groups.

Enhancing Resilience: PIEVC Protocol

To increase efficiency and impact, GIDRM opted for the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol. PIEVC is a tried and tested approach to assess critical infrastructure responses to the changing climate and accompanying risks. PIEVC is a scalable solution that can be tailored to varying needs and contexts. This leads to improved risk perception, thereby better protecting populations, critical infrastructure systems and development achievements. As such, the PIEVC Protocol serves as a valuable support mechanism towards risk-informed decision-making, planning and implementation processes.

Climate risk assessments like the PIEVC Protocol are always a means to an end: strengthening resilience and safeguarding development gains. Their findings must be integrated into planning and decision-making processes to be effective.

Enabling Risk-Informed Development

In Lesotho, the application of the PIEVC Protocol was complemented with a conceptual and integrated framework called the "Enabling Environment for Risk-informed Development" (EE4RID).[22] This framework describes a set of policy, regulatory, organizational, procedural and cultural conditions that can institutionalize risk-informed approaches within development decision-making.

Guided by EE4RID Framework, GIDRM conducted a baseline analysis of the broader context underlying the PIEVC assessment. The analysis captured the current state of affairs, priority actions and good practices, as well as constraints and challenges regarding enabling conditions for RID in Lesotho. Based on this analysis, concrete levers were identified to strengthen the enabling environment for RID through a successful implementation and use of PIEVC assessment. These results were then embedded into the assessment process.

Stakeholder Engagement and Assessment Process

The PIEVC process began with an inception workshop, where stakeholders defined the assessment scope and shared experiences on climate impacts and infrastructure management in the region. A series of activities followed to support the risk assessment, including online training sessions on PIEVC and data collection and a preliminary climate change likelihood analysis. Stakeholders reconvened for a risk assessment workshop to validate climate impact models, score the severity of climate impacts, and develop context-specific recommendations. Complementary tools, such as PIEVC High-Level Screening Guide (HLSG) and PIEVC Green Tool, were used to assess vulnerabilities across three interconnected geographical scales: the watershed and reservoir, the dam itself, and the water users' scale.

Stakeholder involvement from various sectors was crucial throughout the process, contributing to data provision, climate impact insights, and risk scoring. Expert interviews further enriched the assessment, ensuring a comprehensive understanding of the system under evaluation.

Ultimately, the PIEVC methodology and the EE4RID framework proved to be directly complementary. Their joint application in this piloting activity demonstrated the potential and sectoral applicability of the EE4RID Framework and provided important evidence for the mainstreaming of risk-informed development in Lesotho.

[22] GIDRM (n.d.). What is the Enabling Environment for RID? The Global Initiative on Disaster Risk Management. HYPERLINK "https://www.gidrm.net/en/gidrm/ee4rid#:~:text=The%20Enabling%20Environment%20for%20risk,process%20and%20decision%2Dmaking%20processes"https://www.gidrm.net/en/gidrm/ee4rid#:~:text=The%20Enabling%20Environment%20for%20risk,process%20and%20decision%2Dmaking%20processes

Metolong Dam System, Lesotho
Source: GIDRM

Learnings and Impact

Considering the systemic, multi-dimensional and interconnected nature of risk, identifying suitable entry points for RID requires collaboration across sectors and levels. In Lesotho, GIZ hosted the PIEVC assessment under the National Integrated Catchment Management Program (ReNOKA). ReNOKA's mandate and partnerships were crucial for raising awareness and mobilizing multidisciplinary expertise for PIEVC assessment. This collaborative approach ensured transparency, co-ownership, and collective accountability.

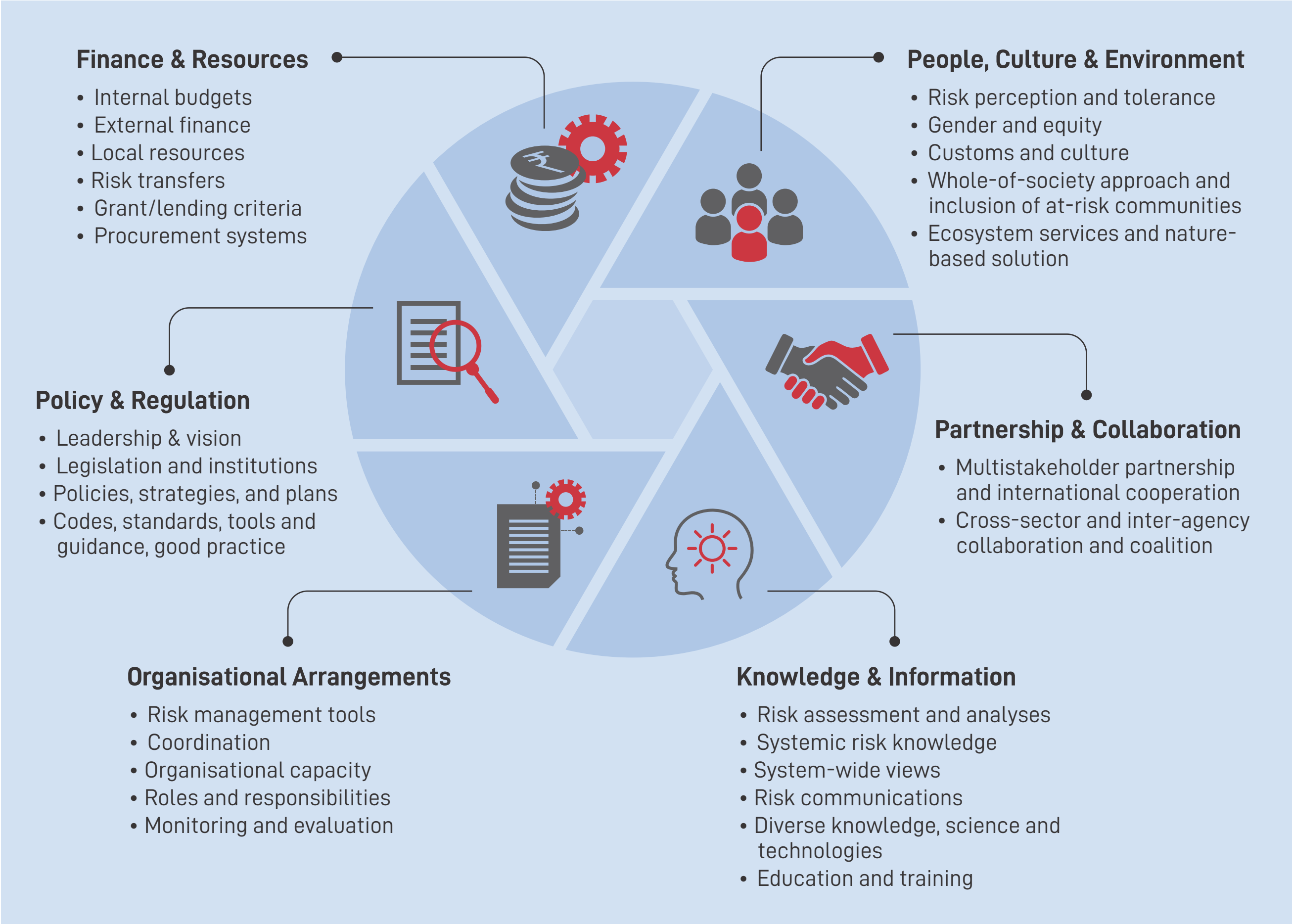
The assessment results and recommendations were directly used to inform new catchment management plans in Lesotho, addressing vulnerabilities, and implementing adaptation measures. GIZ's engagement with SADC Water Division, Disaster Risk Reduction Unit, Orange-Senqu River Commission (ORASECOM), and other river basin organizations (RBOs) helped to upscale the lessons learned from Lesotho to the regional level. This promoted strategic discussions on systematically integrating climate risks into transboundary water management and critical infrastructure investment planning.

One major challenge was bridging diverse perspectives on environmental risks and critical water infrastructure resilience. Stakeholders ranged from government agencies to community leaders, requiring the establishment of a common understanding of risk and the technical aspects of the assessment. To address this, the initiative emphasized capacity-building and awareness-building activities, including the inception workshop, online training, and expert interviews. Data availability and quality also posed challenges, which were addressed through collaborative data gathering, refined methodologies, and stakeholder engagement.

The initiative fostered collaboration and a shared sense of ownership among stakeholders, involving over 50 practitioners, managers, decision-makers, and community leaders. This participatory approach enriched the assessment with diverse insights, which were incorporated into decision-making. By strengthening inter-sectoral relationships, enhancing local capacities for risk assessment and adaptation, and by integrating risks into national policies, such as Lesotho Water Act and National Strategic Development Plan, the initiative fostered long-term resilience. Considering both grey and green infrastructure promoted a holistic approach to critical infrastructure management, benefiting both the environment and communities.

The initiative in Lesotho demonstrated strong scalability potential through its integration into national policies and regional frameworks, which set a precedent for other regions. Sustaining established partnerships and knowledge-sharing is crucial for expanding the initiative's impact. The EE4RID Framework proved to be adaptable to various sectors, scales, geographies, climatic conditions and social settings, making it broadly applicable. The positive reception from SADC, ORASECOM and other RBOs underscores the potential for regional collaboration and the application of the EE4RID Framework across Southern Africa and beyond.

Figure F3.1: Six dimensions and the specific components of the EE4RID Framework



Source: Risk-informed Development: Why It Matters

Additional Information

Video Links

GIZ. (2022). Promoting resilient critical infrastructure for risk-informed and sustainable development. YouTube. https://www.youtube.com/watch?v=UgSAFan5PXI

GIZ. (2023). The enabling environment: Transforming development to minimize risk creation. YouTube. https://www.youtube.com/watch?v=p8DTUJORR-c

Readings

GIDRM. (2022). Strengthening critical infrastructure resilience through risk-informed development in Lesotho's water sector. In Global Initiative on Disaster Risk Management (GIDRM). https://www.gidrm.net/user/pages/get-started/resources/files/GIKRM_III_Factsheet_EN_Lesotho.pdf

GIDRM. (n.d.). Tools for strengthening the resilience of infrastructure systems and services in the SADC region. https://www.sadc.int/sites/default/files/2023-12/2023_12-05_EN%20-%20PIEVC-SADC_Publication.pdf

GIDRM. Southern Africa. https://www.gidrm.net/en/gidrm-phase-3/where-we-work/southern-africa

GIDRM. (n.d.). Risk-informed Development: Why It Matters. https://www.preventionweb.net/media/95757/download?startDownload=20250120

PIEVC Program. https://pievc.ca/overview-and-how-to-access-the-pievc-resources/

PIEVC Practitioners' Network. https://pievc-practitioners-network.earthnet.org/

F4: Government-led Policy Framework for Building National Resilience, Japan

Japan

Submitted by:
International Cooperation Division, Government of Japan

Introduction to the Initiative

In Japan, where large-scale natural disasters occur frequently, the Basic Act on National Resilience was enacted in 2013 based on the idea of pre-disaster prevention measures. This led to the formulation of basic and regional plans and the promotion of measures related to national resilience, such as infrastructure development.

In response to recent large-scale natural disasters, a three-year emergency plan and a five-year acceleration plan were formulated for implementation of urgent measures.

As a result, measures worth US$413 billion were implemented over the 10 years from 2013. Every year, ministers from each ministry convene at the Prime Minister's command to follow up on the basic plan and discuss future measures, accelerating the strengthening of the nation's resilience.

Detailed Description of the Initiative

This initiative focuses on governance and serves as a reference for government-led national resilience policies and their implementation for building a resilient country. Figure F4.1 provides an overview of the initiative.

The briefing on the process of the policy is as follows:

- In 2013, the Basic Act for National Resilience Contributing to Preventing and Mitigating Disasters for Developing Resilience in the Lives of the Citizenry was enacted. Recognizing the increased frequency of large-scale natural disasters, the Act emphasized the importance of comprehensive and systematic implementation of measures for disaster prevention, mitigation, swift recovery, and reconstruction, ultimately leading to international competitiveness.
- In 2014, to achieve the four basic principles stipulated by the Act, the government set out "eight goals that should be achieved in advance", and 45 "worst-case scenarios that should not occur" were identified, that could hinder achieving the eight goals. To overcome the worst-case scenarios, vulnerability assessment was conducted on each program of the relevant ministries to comprehend the situation. Considering these factors, a Basic Plan was created by National Resilience Promotion Headquarters, consisting of the Prime Minister and all Cabinet Ministers, while also taking into account the opinions of the National Resilience Promotion Council. The basic plan is reviewed approximately every five years. In addition, National Resilience Promotion Headquarters formulates an annual plan based on it, utilizing quantitative indicators each year, and steadily promoting measures using the Plan-Do-Check-Act (PDCA) cycle. Alongside the national plan, regional plans for national resilience are also being created at the prefectural and municipal levels, to promote measures to build resilience in each region.
- In 2018, as an additional measure to the basic plan, the Cabinet decided to implement a three-year emergency measure worth US$49 billion from 2018 to 2020. This was implemented in response to the severe damage caused by heavy rains, typhoons and earthquakes in 2018, leading to the loss of many lives and disruption of critical infrastructure. The emergency measure included 160 programs aimed to maintain the functioning of critical infrastructure for disaster risk reduction, safeguard human lives, and protect economic development and livelihoods.

- In December 2020, due to increasing severity and frequency of meteorological disasters and in preparation for predicted large-scale earthquakes (Nankai Trough earthquake), the Cabinet decided to compile a five-year acceleration plan worth US$105 billion in addition to the basic plan, for the fiscal years 2021 to 2025. The plan included 123 programs to improve aging infrastructure through preventive maintenance and promote digitalization to efficiently advance measures related to national resilience.

The outcomes of the national resilience policy efforts include river improvements and strengthening disaster resistance of educational facilities, medical facilities, and social welfare facilities, as well as developing and strengthening infrastructure. Additionally, the capacity building of disaster dispatch teams has been a focus. These measures have steadily progressed, and there are numerous examples of their effectiveness in recent disasters. One example is an elementary school in the disaster-affected area of the M7.6 Noto Peninsula earthquake that occurred on 1 January 2024. The building had been made earthquake-proof, and the affected people were quickly accommodated in a safe shelter. For the quantitative evaluation of the progress of individual measures, the government sets key performance indicators and other specific numerical indicators and constantly reviews such indicators in response to changes in circumstances.

Learnings and Impact

To effectively prepare for large-scale natural disasters, it is imperative to implement comprehensive, well-planned measures that address preparedness and mitigation strategies as well as swift recovery and reconstruction.

Key points of implementing the policy include:

Setting goals based on the principles

In Japan's case, principles are stipulated in the Act and are: 1) Prevent human loss by any means; 2) Avoid fatal damage to important functions for maintaining administration as well as social and economic systems; 3) Mitigate damage to property and facilities and prevent expansion of damage; and 4) Achieve swift recovery and reconstruction. Based on these principles, eight goals were formulated.

Identifying worst-case scenarios

Worst-case scenarios are those that may hinder the achievement of the goals. In Japan's case, an example of worst case is "an extensive human loss due to a wide area large-scale tsunami, etc.", which is placed under the goal of protect human lives to the utmost extent.

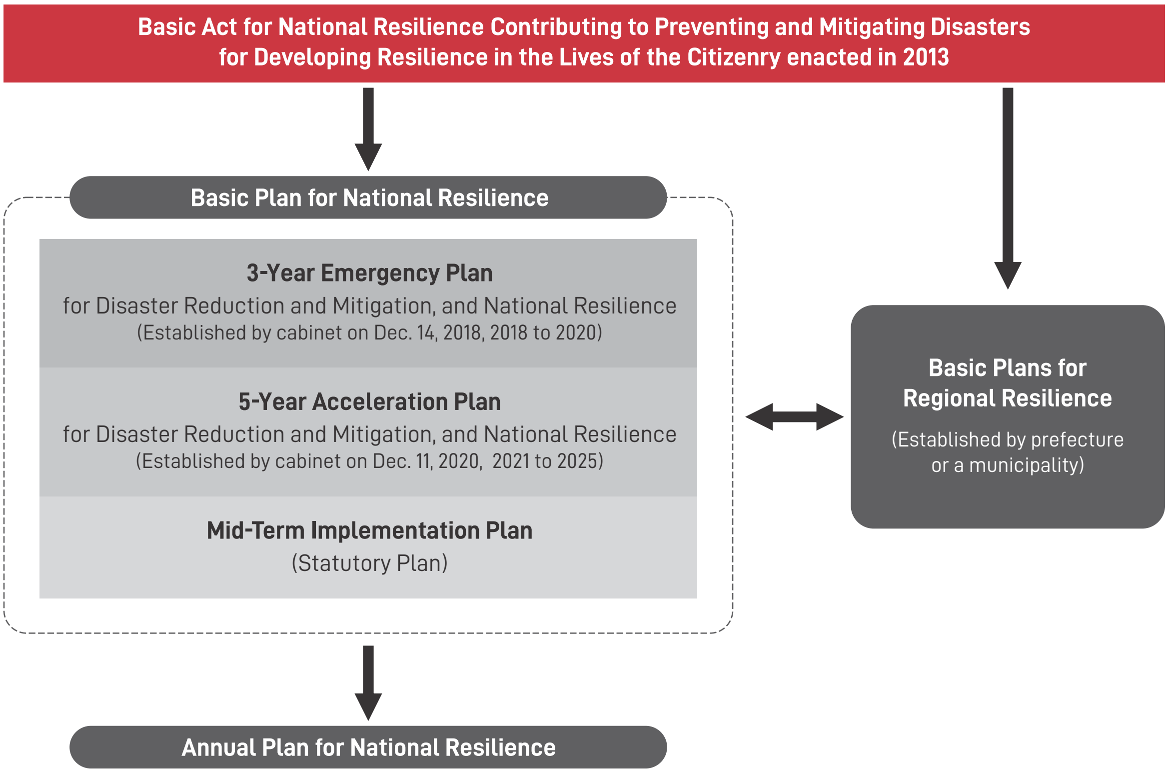
Setting key performance indicators

Key performance indicators shall be set for properly ascertaining the achievement level and progress of each program, based on which assessment shall be conducted each fiscal year for respective programs with regard to specific measures that were deployed.

Conducting vulnerability assessments

These assessments are conducted by every program related to National Resilience.

Figure F4.1: Framework for Building National Resilience, Japan



Additional Information

Readings

Cabinet Secretariat, Japan. (2013). Basic Act for National Resilience contributing to preventing and mitigating disasters for developing resilience in the lives of the citizenry. In Basic Act for National Resilience. https://www.cas.go.jp/jp/seisaku/kokudo_kyoujinka/pdf/khou1-2.pdf

Building National Resilience. (n.d.). https://www.cas.go.jp/jp/seisaku/kokudo_kyoujinka/index_en.html

Action Plan for National Resilience. (2014). https://www.cas.go.jp/jp/seisaku/kokudo_kyoujinka/en/action_plan.html

National Resilience Promotion Office, Cabinet Secretariat. (n.d.). Creating a strong and flexible country. https://www.cas.go.jp/jp/seisaku/kokudo_kyoujinka/en/e01_panf.pdf

F5: Advancing a Resilient Built Environment, Bhutan

Bhutan

Submitted by:
The World Bank

Introduction to the Initiative

With support from the Global Facility for Disaster Reduction and Recovery (GFDRR), Bhutan has moved forward on a comprehensive policy and legislative framework for a resilient built environment. Major accomplishments include a construction quality compliance mechanism (CQCM), which will serve as a framework for regulating and enforcing compliance with national building regulations. These efforts helped to pave the way for the World Bank's approval of a US$14.8 million line of credit that will provide immediate liquidity for Bhutan in the aftermath of a disaster or emergency, while also supporting policy actions designed to strengthen the country's disaster risk management capacity.

Detailed Description of the Initiative

From the COVID-19 pandemic to human resource constraints, recent years have seen the Royal Government of Bhutan grapple with a range of challenges as the country strives to achieve a more sustainable development path. Recognizing Bhutan's continued vulnerability to natural hazards and climate change, the government has remained committed to its longstanding efforts to build disaster and climate resilience for the long term.

Prominent among those efforts has been the government's drive, led by the Ministry of Infrastructure and Transport and the Ministry of Home Affairs, to strengthen Bhutan's comprehensive policy and legislative framework for crisis preparedness and a resilient and green built environment. Drawing on technical and financial assistance from GFDRR and the World Bank, and in partnership with EU-South Asia Capacity Building for Disaster Risk Management Program and the Japan-World Bank Program for Mainstreaming Disaster Risk Management in Developing Countries, Bhutan has achieved several key milestones in developing that framework.

The government has drafted a construction bill and housing bill that will jointly provide an overarching legislative framework for the country's resilient built environment. These efforts were made alongside revisions to the country's national building regulations, designed to strengthen their enforcement and improve quality and safety standards for the construction of buildings in Bhutan. Key improvements made in the revisions include a centralized, online approval system for compliance by all engineered buildings; prohibitions on the use of construction materials with high global warming potential such as chlorofluorocarbons; and requirements that all technical drawings must address fire safety requirements.

Furthermore, government officials have drafted amendments to the Disaster Management Act of Bhutan, passed in 2013, which will strengthen the country's disaster and emergency preparedness and response by integrating climate change impacts and pandemic management into the country's principal disaster law. The drafting of amendments to the law was taken up in parallel with the development of the National Disaster Management Contingency Plan, which adopts a whole-of-government approach to disaster and emergency preparedness and response.

At the same time, officials have developed a construction quality compliance mechanism (CQCM), which will serve as a framework for regulating and enforcing compliance with the country's national building regulations across all types of infrastructure and engineered buildings in Bhutan. CQCM defines the roles and responsibilities of public and private stakeholders in the construction sector. It also provides guidance on the formulation of a quality assurance and control framework, including stepwise processes, standard operating procedures, checklists, guidelines on sanctions for noncompliance with quality requirements by contractors and procuring agencies, and relevant rules and regulations. It is anticipated that there will be an important role for the Interim Engineering Council of Bhutan, which was established with support from GFDRR and the World Bank, in registering and certifying construction professionals based on technical qualification criteria.

Bhutan's swift progress on advancing this suite of reforms helped to pave the way for World Bank's approval of US$14.8 million in funding for the country under a Development Policy Financing (DPF) with Catastrophe Deferred Drawdown Option (Cat DDO) package. Cat DDO is a contingent line of credit providing immediate liquidity in the aftermath of a disaster or emergency while also supporting policy actions designed to strengthen a country's disaster risk management capacity. The partnership between Bhutan, GFDRR, and the World Bank in sustaining and deepening reforms over the past decade is informing the preparation of a second Cat DDO operation.

Additional Information

Readings

GFDRR. (2024). Deepening Reforms for a Resilient Bhutan through a Cat DDO. https://www.gfdrr.org/en/feature-story/deepening-reforms-resilient-bhutan-through-cat-ddo

GFDRR. (2024). GFDRR Annual Report 23 – Bringing resilience to scale. World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099836402122412500/idu1296966181302414785188c41e3492095ce66

F6: NCEMA's Standards and Frameworks for Resilient Infrastructure, United Arab Emirates (UAE)

United Arab Emirates (UAE)

Submitted by:
National Emergency Crisis and Disasters Management Authority, Government of the United Arab Emirates

Introduction to the Initiative

The National Emergency Crisis and Disaster Management Authority (NCEMA) has developed frameworks and standards to integrate disaster risk reduction to guide efforts to enhance the resilience of National Critical Infrastructure (NCI). This approach strategizes the 10-principle strategic roadmap established by United Arab Emirates (UAE) and complements the UAE's centennial plan 2071 that outlines government efforts in developing future-focused mechanisms to monitor vulnerabilities in different sectors. These standards and frameworks have guided efforts to enhance the resilience of National Critical Infrastructure (NCI) and the continuity of vital services and products in the country.

Detailed Description of the Initiative

UAE's 10 principles emphasize the importance of sustainability, future readiness, and long-term national resilience. These principles underline the country's commitment to developing infrastructure that is not only robust and reliable but also adaptable to emerging challenges and aligned with the UAE's strategic vision. The three aspects of UAE's approach to infrastructure are (i) continuous development, (ii) future readiness and innovation and (iii) sustainability and environmental responsibility. NCEMA's approach to infrastructure resilience also aligns with these aspects.

NCEMA engages in continuous evaluation and improvement of critical infrastructure so that it can adapt to technological advancements, environmental changes and evolving threats. This ensures that the infrastructure remains resilient in the face of new hazards. NCEMA also advocates for integrating advanced technologies such as AI and IoT in monitoring and enhancing the resilience of critical infrastructure. The use of smart systems to predict potential disruptions and automate responses is a key element in ensuring that infrastructure can withstand and recover from crises. Importance is also given to disaster risk reduction strategies that are aligned with environmental sustainability goals, ensuring that infrastructure development does not compromise ecological integrity.

UAE defines NCI as essential systems, networks, services, and assets — whether physical or non-physical — that are vital to the nation's security, the economy, societal welfare, public health, and safety. If disrupted for an extended period, they may result in the loss of lives or pose a threat to the national economy. NCI sectors are energy, food, water, telecommunication, transportation, finance, healthcare, and government services. UAE approaches infrastructure through the lens of emergency and crisis management, viewing it as an interconnected system of components.

Therefore, to strengthen resilience and ensure infrastructure can handle emergencies, crises and disasters that may threaten its operational continuity and recovery, UAE manages NCI through five phases:

- **Phase 1, Identification:** Recognizing and labelling critical infrastructure as NCI and recognizing its components and interdependencies.
- **Phase 2, Governance:** Establishing frameworks and standards to safeguard and enhancing the ability of NCI to withstand, recover from, and adapt to disasters.
- **Phase 3, Assessment:** Ensuring compliance with national standards and frameworks designed to build resilience into NCI.
- **Phase 4, National Indices:** Developing national indices for comparative evaluation of resilience of NCI.
- **Phase 5, Continual Improvement:** Continuously refining the abovementioned strategies and frameworks based on performance data and emerging challenges.

NCIs are regulated by setting standards and frameworks to ensure compliance, as shown in Figure F6.1. The National Standard for Business Continuity Management System (BCM) NCEMA7000:2021[23] has played a proactive role in addressing potential disruptions by establishing business continuity plans and strategies to ensure the resilience of critical infrastructure, particularly those providing vital services such as energy, water and telecommunications. These preemptive measures ensure that such services continue to operate during crises.

The effectiveness of the standard was demonstrated by the UAE's response to the heavy rains of April 2024. During this period, UAE experienced unusually intense rainfall, resulting in localized flooding. This deluge caused infrastructure strain, road closures, and the potential for service disruptions across key sectors. By identifying and prioritizing critical infrastructure in advance — recognizing that the delivery of essential services depends heavily on this infrastructure — tailored business continuity strategies were implemented. For example, telecommunications services, which rely on digital networks and transmission systems, were safeguarded through the deployment of signal booster vehicles, ensuring uninterrupted service despite challenging conditions.

The standard's effectiveness was further highlighted during the technical system disruptions caused by the CrowdStrike incident which affected computer systems across the world in July 2024. Adherence to standards helped maintain essential services and prevent interruptions through the activation of alternative systems as a business continuity strategy. The rapid recovery and continuity of services prevented major disruptions, emphasizing the importance of having strong national standards and frameworks in place for disaster preparedness, business continuity, and the protection of critical infrastructure.

NCI's phased framework also guides resilience analysis and evaluation of physical critical infrastructure. It plays a critical role in providing the necessary guidelines to safeguard national critical infrastructure against disasters. Four national indexes have been developed to facilitate the process of evaluation of infrastructure. The assessments are conducted by specialized teams, ensuring comprehensive assessment and continuous improvement. These guidelines are continually refined based on collected data and newly emerging challenges. This process ensures that NCI remains resilient and adaptive. Through the abovementioned measures, UAE aims to protect NCI and maintain the continuity of vital infrastructure services post-disaster.

Learnings and Impact

As embedding and maintaining resilience of NCI is a shared responsibility of the federal government, local governments and other key partners including the private sector, it requires effective coordination. Major challenges which were encountered during the implementation of NCI model framework were following,

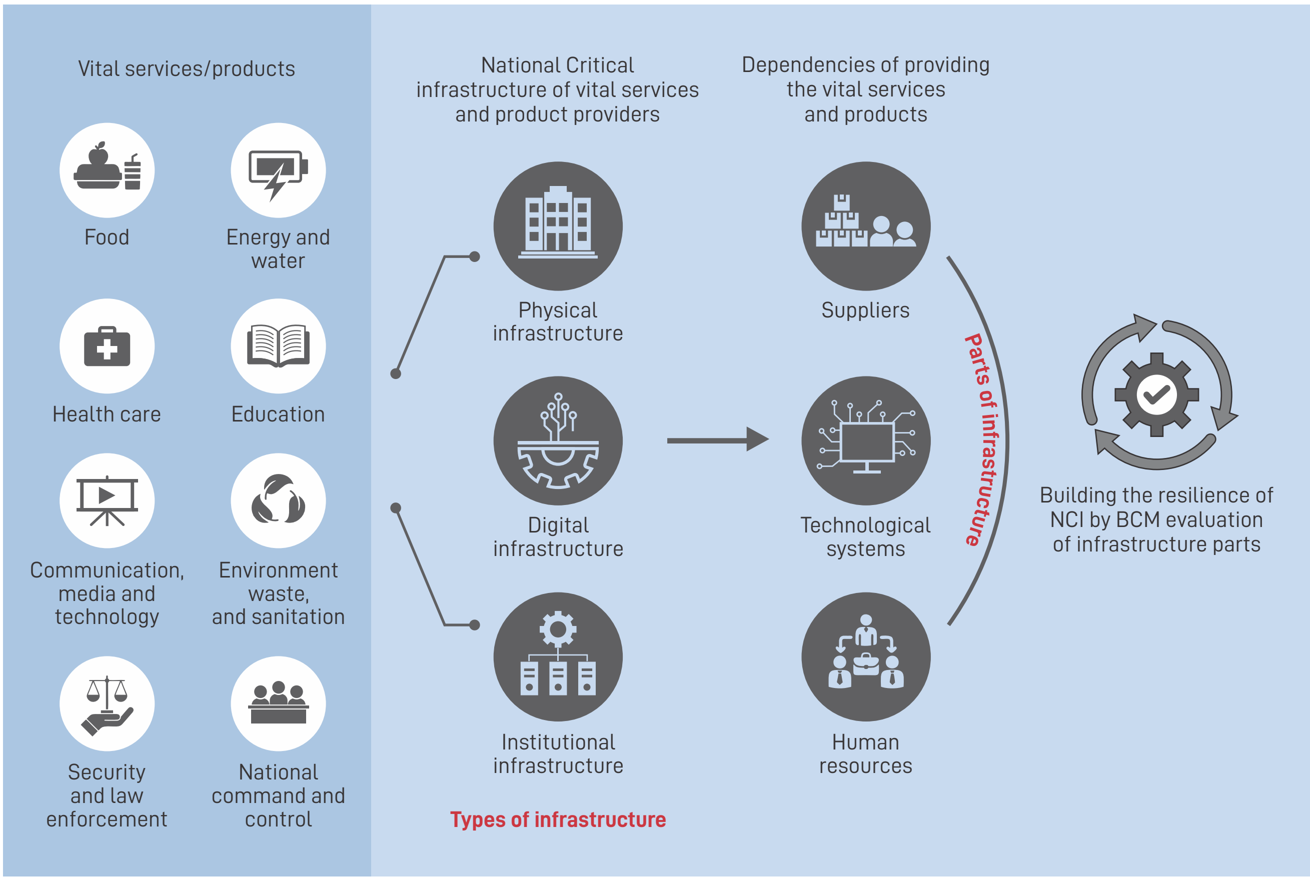
- Achieving a unified understanding of the word "critical infrastructure" amongst all stakeholders at a national scale was difficult, in absence of which a difference in priorities and mismanagement of actions could have happened.
- Engaging the private sector effectively was a challenging task. As many critical infrastructure assets, such as energy, telecommunications, and transportation systems, are owned and operated by private entities, ensuring their full participation and cooperation in aligning with national resilience goals required extensive collaboration, coordination and communication.
- Encouraging private companies to adopt the same level of commitment to building resilience and continuity as public entities, while also balancing business interests.

[23] National Emergency Crisis and Disaster Management Authority. (2021). The National Standard For Business Continuity Management System. https://www.ncema.gov.ae/vassets/48c1c32a/Publication-en.pdf.aspx

To overcome the abovementioned challenges a shared definition of critical infrastructure was created, and a standardized approach was established. This was achieved through collaborative discussions, cross-sector partnerships and shared guidelines. Private sector inputs were also incorporated in NCEMA7000:2021.

These challenges were successfully transformed into opportunities for improvement and joint benefits for both public and private sector were created, fostering greater resilience within the national infrastructure system. Further scaling up of NCI is possible by introducing and updating legislations and policies to provide a supportive regulatory environment, enhance cooperation, set standards and enforce compliance. Additionally, strengthening partnerships between the public and private sectors and other key stakeholders by establishing clear communication channels is crucial.

Figure F6.1: NCI Framework



F7: Promoting Climate and Disaster Resilient Construction Practices: Worldwide Adoption and Use of the Eurocodes Standards, European Union

European Union

Submitted by:
European Commission Joint Research Centre (EC JRC), The European Union

Introduction to the Initiative

The construction ecosystem delivers the built environment needed by the economy and society, having a direct impact on the safety and quality of citizens' life. While adapting to the inevitable impacts of the changing climate, the built environment should have the capacity to withstand the effects of disasters like earthquakes and fires, and to minimize disruption time before recovery. European standards have a key role in achieving a climate-neutral, resilient and circular economy. Within this framework, the Eurocodes are a series of 10 European standards, EN 1990 to EN 1999, comprising 59 parts and providing common technical rules for the design and renovation of buildings and other civil engineering works. They comprehensively cover the basis of structural design; actions on structures; the design of structures; the use of principal construction materials such as concrete, steel, composite steel-concrete, timber, masonry and aluminium; and geotechnical, seismic, and structural fire design.

Detailed Description of the Initiative

The European Commission promotes the use of the EU climate and disaster resilient construction practices worldwide. The Joint Research Centre (JRC) of the European Commission together with the Department for Growth (DG GROW) supports capacity building worldwide by sharing knowledge on the Eurocodes and creating peer-learning opportunities. JRC provides scientific and technical support to the Western Balkan countries and other non-EU countries associated with the Horizon Europe Research Programme, and helps to build their capacity to adapt their own national legislation in the field of construction to the EU legal framework. The activities consist of development of training and guidance material, and worldwide knowledge dissemination and capacity building, to implement advanced construction technologies addressing issues (e.g., earthquakes, fire, climate-related hazards) related to the safety of the built environment.

The JRC contributed to knowledge transfer and building capacities of the national authorities, national standardization bodies, and engineering community of the Balkan countries to implement the Eurocodes and related European standards for construction and incorporate them in their national regulatory frameworks.

Due to the high seismicity of the Balkan region, the implementation of EN 1998 ("Eurocode 8: Design of structures for earthquake resistance") is of crucial importance for improving the seismic resistance of the building stock. To address this problem, in July 2021, the JRC organised the Eurocodes Balkan Summer School on seismic design of concrete buildings with the Eurocodes. As a result of the JRC activities, the Eurocodes are already incorporated in the regulatory frameworks of Montenegro, North Macedonia and Serbia, and the rest of the Western Balkan countries are progressing very well with their adoption.

Georgia, Moldova, and Ukraine became affiliate members of The European Committee for Standardization (CEN) as of 1 January 2023. These countries are elaborating the national documents needed for the adoption and implementation of the Eurocodes. The training and guidance material conceived for the Western Balkan countries can significantly facilitate the adoption of the Eurocodes in these countries.

The regional approach in JRC activities supporting the promotion of Eurocodes worldwide has proven to be successful and beneficial for generating regional collaborations and the creation of communities of practice. In addition, the generated experience and the training and guidance materials elaborated for a region are successfully leveraged to exchange knowledge and experience.

The JRC leads and facilitates key dialogues such as the ASEAN Building and Construction Working Group (ASEAN: Association of Southeast Asian Nations) and the EU-ASEAN Eurocodes Dialogue. The dialogue aims to inform, provide training, and support capacity building for interested and relevant stakeholders (national authorities, chambers of engineers, construction industry associations) in ASEAN countries about the Eurocodes; and facilitates knowledge transfer on the European legislative and standardization framework for the construction sector. The activity takes place in the framework of the Enhanced Regional EU-ASEAN Dialogue Instrument (E-READI) by the department for International Partnerships (DG INTPA). Several ASEAN Member States, because of these activities, have expressed interest in adopting the Eurocodes and receiving further technical support (Cambodia, Brunei, and Malaysia):

- In Brunei Darussalam, in the summer of 2022, a taskforce was set up to assess the suitability of adopting the Eurocodes and at the same time, a regional workshop "Towards increasing awareness of Eurocodes in Brunei Darussalam" took place to outline the needs and the availability of necessary technical assistance in support of the Eurocodes, and its adoption and introduction into the national regulatory framework. After the workshop, a survey operated by the Brunei PUJA Academy has revealed a strong need of training in understanding the Eurocodes among the professionals in the building construction environment in Brunei.
- The Department of Standards of Malaysia has adopted six Eurocodes. Malaysian experts are currently developing National Annexes to them; and have asked JRC for support (technical reports, other national annexes to consult, expert support). Malaysian experts have access to the Eurocodes Database of Nationally Determined Parameters (managed by the JRC) to explore different national practices while adopting the Eurocodes.
- A regional capacity-building workshop in Singapore on the Eurocodes was held in October 2023. Communication exchanges are continuing with ASEC (ASEAN Secretariat) and the Building and Construction Working Group (BCWG) within it. The Eurocodes Dialogue Concept Note is under revision to align it better with the views of BCWG.

Learnings and Impact

The activities in Southeast Asia have demonstrated the importance of prior assessment of local awareness on Eurocodes and of community building and networking – keeping all parties informed, interested and involved.

The current state of adoption of the Eurocodes worldwide is:

- The Eurocodes are adopted in the 27 EU + 4 European Free Trade Association (EFTA) Member States, and in the United Kingdom.
- The Eurocodes are adopted or are in the process of adoption in 9 non-EU/EFTA countries whose National Standards Bodies are full members of CEN, as well as in 13 countries with other affiliations status in CEN.
- 36 other countries have expressed interest in the adoption of the Eurocodes.

F8: Climate-informed Codes, Standards and Guidance, Canada

Canada

Submitted by:
Infrastructure Canada (INFC), Government of Canada

Introduction to the Initiative

Since 2016, Infrastructure Canada (INFC) has been instrumental in supporting world-leading research to integrate climate information into resilience planning for buildings and infrastructure through new and updated design data, construction specifications, decision tools, guidelines, standards, and changes to national codes. During the 2021–2026 period, INFC is supporting the National Research Council (NRC)-led Climate Resilient Built Environment (CRBE) and the Standards Council of Canada (SCC)-led Standards to Support Resilient Infrastructure Program (SSRIP) initiatives.

Detailed Description of the Initiative

The CRBE initiative builds on the foundational work and success of the ongoing 2016– for flood mitigation, buildings, roads, water/wastewater systems, bridges, urban heat mitigation, and guidance for northern, remote and Indigenous communities.

SSRIP has delivered standardized projects to address resilience needs since 2016. By 2028, the program will have advanced 50 new and updated standards and related guidance that incorporate climate change considerations for infrastructure and buildings across Canada with particular focus on heat, flooding, the Canadian North, integrated risk management, natural infrastructure and low-carbon asset resilience.

Installation of a thermosyphon, geo-cell to reduce permafrost degradation and other field research activities
Source: Infrastructure Canada (INFC), Government of Canada.

Installation of a thermosyphon, geo-cell to reduce permafrost degradation and other field research activities
Source: Infrastructure Canada (INFC), Government of Canada.

Learnings and Impact

The timely delivery of updated guidance has proven beneficial for communities, enabling them to build back better after climate disasters and extreme events. For example, guidance to address the impacts of wildfires on communities (National Guide for Wildland-Urban Interface Fires) published in 2021 is being used by the town of Lytton, British Columbia, to rebuild after wildfires destroyed much of the city that same year.

Sustained outreach and engagement with infrastructure owners, managers and designers is essential to increase rapid, early adoption of newly developed standards, guidance and tools. Swift change in practice must be encouraged alongside updates to the national building codes (a lengthier process).

Under new climatic conditions, relying on historical climate information has crucial implications for infrastructure design, leading to significant potential for maladaptation and greater financial and socioeconomic risks. Tools such as the NRC-developed Design Value Explorer can accelerate the use of future projected climate information to inform infrastructure design when using national codes.

The projected impact of INFC's work on climate-informed codes, standards and guidance is significant, as reflected by an independent study reporting that using some of the key resulting guidance produced under CRBCPI could save Canada an estimated Can$4.7 billion annually for new construction.

F9: The National Seismic Prevention Plan, Italy

Italy

Submitted by:
Italian Civil Protection Department, Government of Italy

Introduction to the Initiative

Following the 2009 L'Aquila earthquake, which caused 309 fatalities, the Italian government decided to implement a comprehensive National Seismic Prevention Plan (NSPP). The NSPP, issued by Decree-Law n. 39/2009 turned into Law n. 77/2009, provided at first 965 million euros, distributed over seven years and ruled by specific ordinances.

The Plan is under the coordination of the Italian Civil Protection Department (ICPD), and its implementation at a territorial level is the responsibility of regional administrations, representing the main stakeholders in the entire process. The goal of the NSPP is the reduction of human losses; to pursue seismic risk reduction through a comprehensive approach, balancing structural and non-structural measures to support resilience of strategic and private infrastructure; and to improve the response of the civil protection system in case of emergency.

Detailed Description of the Initiative

Grants through the NSPP initiative are concentrated in the most hazardous areas of the country, which includes around 3,800 municipalities concentrated mainly in seismic zones 1 and 2 (out of four). In total, 17 out of 20 Italian regions benefit from NSPP grants. The economic resources issued by each ordinance are distributed among the participating regions according to regional seismic risk indices, considering the probability of building collapse expected in each territory in case of an earthquake, shown in Figure F9.1.

Actions financed by the NSPP are: (1) Seismic Microzonation studies (SM) and Limit Condition for Emergency analysis (LCE); (2) Seismic retrofit interventions or reconstruction of public buildings and infrastructural items of strategic interest or critical for the consequence of their collapse (iii) Seismic retrofit interventions or reconstruction of private buildings. These actions are implemented by regions, through individual programs considering the requests from local authorities and private beneficiaries, where co-financing is encouraged.

The first measure encompasses two different tools at urban scale. SM studies are aimed at identifying unstable and stable areas and possible soil amplification effects in municipal or inter-municipal areas, according to different levels of analysis ranging from level 1 to level 3. LCE analysis is based on contingency plans at the urban level and are intended to check critical elements (such as buildings, infrastructure and emergency areas) that should resist the earthquake in order to ensure prompt and efficient management of the emergency phase. To date, most MS studies and LCE analysis financed have been primarily in territories of seismic zones 1 and 2, representing 50 percent and 40 percent of the Italian municipalities respectively.

Retrofit interventions granted by the NSPP are destined for public buildings and infrastructure that are critical for civil protection purposes, as well as to private and productive buildings. Intervention types admitted include local strengthening, global seismic upgrading or demolition and reconstruction, the definitions of which comply with those provided by the Italian technical standards for construction (Minister of Infrastructure Decree, D.M. 2018).

Around 90 percent of the total endowment is allocated to seismic vulnerability reduction interventions, 81 percent of which is directed at public buildings and infrastructures and the remaining to the private sector. With respect to interventions directed at critical infrastructure or public buildings, the grant for each structural intervention depends on the type of intervention and on the seismic safety index of the building/infrastructure before the intervention (SLV). To date, 1,323 structural interventions directed at strategic and relevant buildings have been funded, 21 of which have been on bridges and viaducts and the remaining directed at buildings. Around 53 percent of the retrofitted buildings host administrative activities, 24 percent are school buildings, 11 percent are hospitals and health facilities, 6 percent comprise security activities (such as fire brigade and police headquarters), and 6 percent are for other functions. Moreover, 25 percent of the reinforced buildings host emergency coordination centres in case of a seismic event. Around 31 percent of interventions has been co-funded by local public administration, thus extending the economic capability of the Plan. To date, 44 percent of the retrofitting interventions in the public sector has been concluded and the remaining is in progress.

Interventions directed at private buildings were granted by NSPP until 2018, when further financial incentives for private owners were planned by the state. To date, total interventions amount to 3,532, 70 percent of which have concluded works. In these years, the ICPD, in order to best perform its role as promoter and coordinator of the Plan, has founded two monitoring and coordination bodies at a national level, joined by ICPD and relevant stakeholders (regions and local authorities): (1) the Technical Table (TT), relevant to structural interventions in public and private assets; and (2) the Technical Commission (TC), directed at seismic micro-zoning studies and analysis of the limit condition for emergency assessment. These bodies monitor, share experiences and support stakeholders and have played a central role in the execution and sustainability of the Plan.

Learnings and Impact

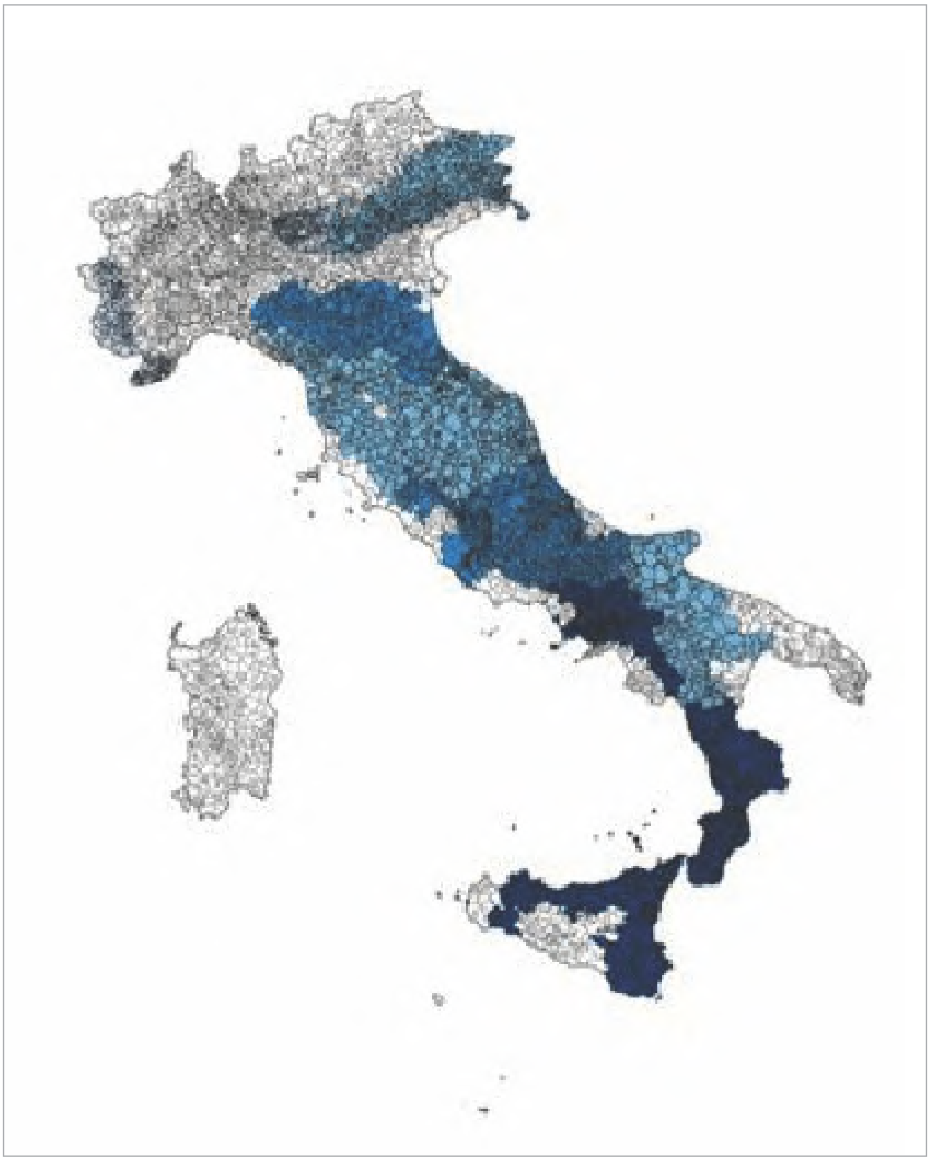
The results achieved by the NSPP have been considerable, despite a diversified state of implementation at territorial level which has required this Department to issue further measures to adjust the strategy for specific needs.

Measures introduced by the Plan have generated a virtuous process resulting in various positive outcomes:

- The multi-level articulation of the Plan, performed through central coordination and a peripheral local system, has generated positive results. Regions, through an effective interaction with local authorities, are the right territorial bodies that can guarantee adequate implementation of the Plan and take decisions and define priorities based on the real needs of the territory, in terms of desirable interventions and civil protection needs.
- The regions do not follow the Plan at the same pace, partly due to the administrative undersizing of the local authorities with whom the regions need to interact. A form of local technical support is being provided by ICPD according to a subsidiarity approach, which aims to improve the capability and performance of lagging territorial bodies.
- The close interaction between SM studies and LCE analysis with retrofit interventions allowed decision-makers to optimize intervention priorities, and mainstreamed a systemic approach to the whole emergency system and complete integration across structural and non-structural prevention tools.
- The public resources allocated have stimulated activation of additional resources (co-financing) by public bodies and private beneficiaries of interventions, also helping to boost the local economy, especially in the building sector. For structural interventions, for example, co-financing amounts to 10% of the total resources allocated by the state for a particular task.

The Plan was a good driver to generate individual and administrative attention to seismic risk and increase risk awareness and a culture of prevention. For this, its dissemination and communication through institutional channels has come to be of significant importance.

Figure F9.1: Total Funds Assigned to the Italian Regions by NSPP

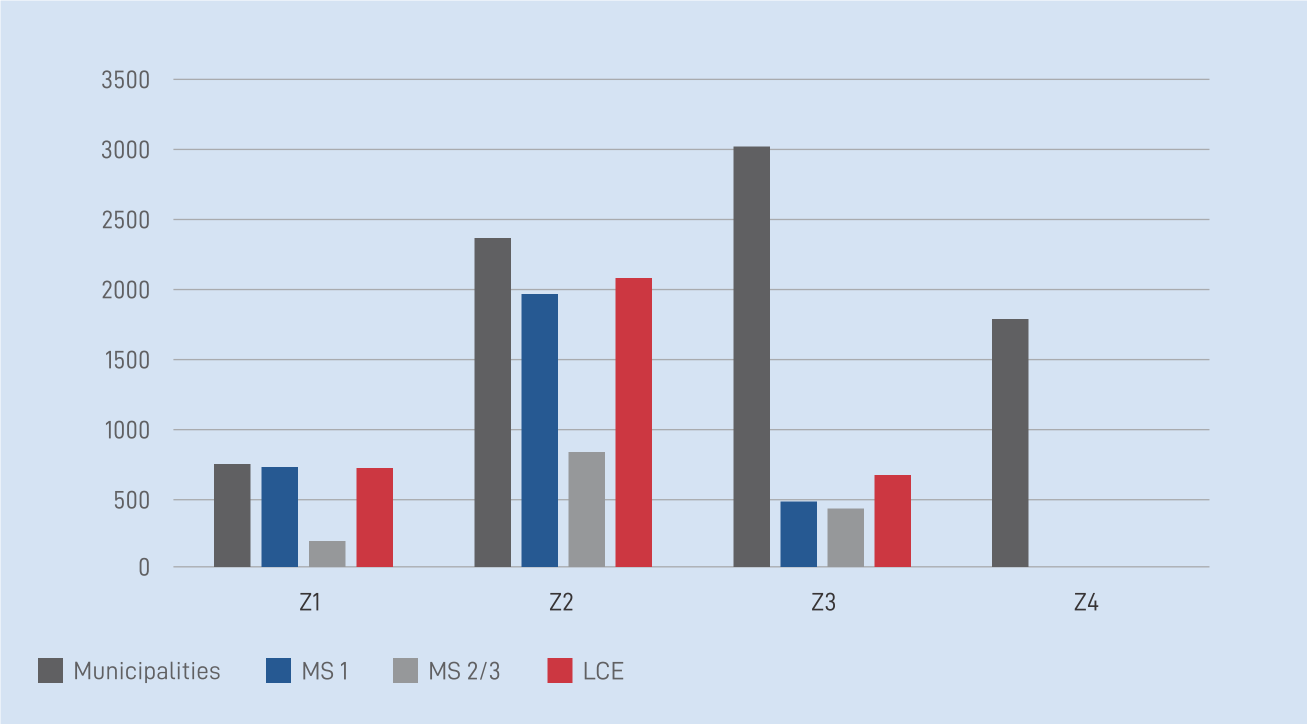


Legend

- € 0
- € 0 - € 15,000,00
- € 15,000,000 - € 60,000,00
- € 60,000,00 - € 90,000,00
- € 90,000,00 - € 170,000,00

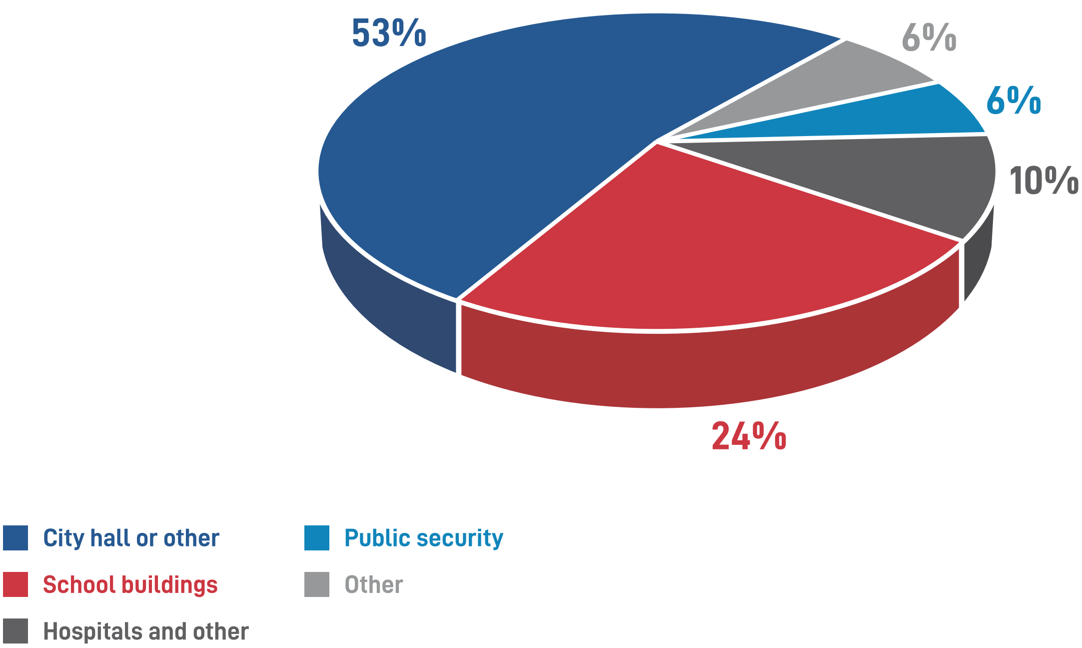
Source: Italian Civil Protection Department, Italy

Figure F9.2: Distribution of MS Studies and LCE Analysis Per Seismic Zone



Source: Italian Civil Protection Department, Italy

Figure F9.3: Distribution of Public Building Types Subjected to NSPP Interventions



Source: Italian Civil Protection Department, Italy

F10: Resilience Ratings System, Australia

Australia

Submitted by:
Resilient Building Council (RBC), Government of Australia

Introduction to the Initiative

Jointly funded by the New South Wales State Government and the Australian Government State Disaster Risk Reduction Package, RBC's Resilience Rating system measures the disaster resilience and energy efficiency level of buildings. It provides an independent global standard to rate and reward the climate resilience dimension of new and existing buildings. The Resilience Ratings will make it easier to adapt homes to the changing climate by providing a single home assessment framework mechanism for harmonized action plans and ratings certification capability for bushfires, storms, floods, cyclones, heat waves, thermal comfort and energy efficiency.

Detailed Description of the Initiative

RBC has established a unique, multidisciplinary collaboration of independent experts, including research scientists, structural engineers, fire safety engineers, hydrologists, building designers, actuaries, and materials chemists, to apply science and evidence so that it is easily communicated and actionable. The system works by assessing site-specific future climate risks and measuring the home's vulnerability. It provides households with a list of evidence-based, tailored actions to adapt their home, improve their Resilience and Energy Efficiency Ratings and enable access to financial incentives.

This innovative system is designed to accelerate climate resilience action and investment by providing access to credible, usable market mechanisms for capital, insurance, finance and property markets to recognize and reward climate resilient assets.

The Bushfire Resilience Rating Self-Assessment app, funded by the Australian Government Disaster Risk Reduction Package, puts the Resilience Ratings program into the hands of households via a free self-assessment app. The app helps households identify vulnerabilities of their homes to local bushfire risk, provides tailored implementable actions to mitigate their risk and measurably improves the survivability of their homes.

The Bushfire Resilience Rating is calculated using a novel Probability of House Loss Model (developed by RBC in 2018), utilising future bushfire risk data from the Australian Government-funded CSIRO National Bushfire Intelligence Capability system. The Bushfire Resilience Rating system is the first scientific model to calculate bushfire-linked building performance.

The free Bushfire Resilience Rating Home Assessment app empowers people to make informed decisions about their bushfire risk and vulnerability, and puts practical, evidence-based tools for improving bushfire resilience in their hands. Various elements within the assessment framework are as follows:

- Using the app, households enter their address to assess the risk of bushfire at that site.
- Next, households are asked a series of questions about their home, landscaping, and nearby structures.
- A Bushfire Resilience Rating (1 to 5) is then provided for the property along with a tailored action plan of evidence-based, site-specific measures that will achieve a higher rating. For example, mitigation measures might relate to adapting a home's roof, decking or garden to measurably increase bushfire resilience.
- Households will be encouraged to maintain their Bushfire Resilience Rating through annual self-assessment. Industry and governments will be encouraged to provide incentives for the upgrade and maintenance of Resilience Rated property.

The Bushfire Resilience Rating recognizes and rewards well-prepared property and communities. The free app empowers everyday Australians with the trusted, customized information they need to make their homes more resilient to bushfire.

RBC team meeting
Photo Credit: Government of Australia

RBC rating workshop
Photo Credit: Government of Australia

Learnings and Impact

RBC developed the Resilience Ratings program to inform, motivate and reward well-prepared property and communities. A 5 star Resilience Rating means that the household has taken the highest level of action to reduce their vulnerability to local climate risk. For example, a 5 star Bushfire Resilience Rated property has reduced the likelihood of building ignition to less than 1.5 percent, whereas a 1 Star Bushfire Resilience Rated property has a likelihood of ignition of more than 40 percent.

Applied post-bushfire building loss research, engineering first principles and expert consensus identified the major causes of property and life loss which is the basis of the Resilience Rating model. The Resilience Rating system has been calibrated and verified through post-disaster building damage research, materials testing and insurance claims data.

During the development phase of the system, 432 households were provided with the Bushfire Resilience Rating Self-Assessment App. 172 of those households used the app to undertake some of the recommended actions, which led to an average reduction in the likelihood of building ignition by 37 percent. Pilot participants were also offered a whole-of-mortgage interest rate discount from the National Australia Bank to recognize and reward Bushfire Resilience Rating improvements.

The free app was provided to households rebuilding after the 2019-20 Black Summer bushfires to encourage building beyond minimum standards, resulting in 5 Star Bushfire Resilience Rated homes. RBC also has partnerships with emergency services, local governments, community organizations, banks, insurers and builders to help promote the app.

- RBC conducted a two-year bushfire resilience and energy efficiency home retrofit research program to support the development of the ratings system. The independent research found improving bushfire resilience of homes provided an average carbon abatement of 7.4 tonnes CO2e.
- It also concluded that integrated energy efficiency and resilience retrofits mitigates the risk of adverse outcomes (e.g., the vulnerability to disasters being increased by energy-efficiency retrofits) and maximizes the efficiency and effectiveness of the retrofits by prioritizing actions that provide substantial co-benefits and avoids duplication of resource use.
- Climate resilient homes deliver measurable social and economic benefits including avoided death and injury, improved health and wellbeing, protection/improvement of property values, access to affordable insurance, access to finance, avoided property damage and loss, energy savings, housing security, and contribution to whole-of-community resilience and prosperity.
- A property for sale or rent should attract higher returns if it advertises its high Resilience Rating. Importantly, consumers are informed about the resilience of the property, thereby driving awareness and behaviour change. Insurers are more likely to stay in the market, keeping premiums competitive, which also enables household access to finance.

The Plan was a good driver to generate individual and administrative attention to seismic risk and increase risk awareness and a culture of prevention. For this, its dissemination and communication through institutional channels has come to be of significant importance.

Several industry co-benefits also make themselves manifest:

- Reducing insurance claims costs places downward pressure on household premiums.
- De-risking mortgage books incentivizes lenders to provide cheaper finance to households.
- Greater adoption of disaster resilient materials stimulates innovation and supply chains, putting downward pressure on prices.
- A larger market size also generates jobs in the resilient, sustainable building, manufacturing and assessment sectors.
- Informs the building industry and improves average building design performance.
- A greater rate of household adoption drives greater whole-of-community climate resilience.

The project also includes a database of assessed property, which will provide an unprecedented catalogue of building and resilience data. This will enable scientific research into the performance of the Resilience Rating system after disasters, with specific insights into how safety systems, materials, buildings, infrastructure, and emergency planning have performed.

- RBC will be able to report to government, building codes and standards committees, industry, and the community about the performance of resilience measures, ensuring continual improvement.
- It proposes to expand the Bushfire Resilience Rating Self-Assessment app to flood, storm, cyclone, heat wave, electrification, and energy efficiency, to enable free, equitable access to climate risk information and tailored adaptation plans.
- It seeks to deliver the world's first independent global standard to measure the disaster resilience of buildings and enable generation of financial benefits.

F11: Strengthening Critical Infrastructure Resilience through the Implementation of UNDRR's Principles for Resilient Infrastructure, Costa Rica

Costa Rica

Submitted by:
United Nations Office for Disaster Risk Reduction (UNDRR)

Introduction to the Initiative

The UN Office for Disaster Risk Reduction (UNDRR) developed the Principles for Resilient Infrastructure to address gaps in current infrastructure planning, financing, design, development, and operation, which do not fully consider either the interdependent nature of infrastructure and services, or the increasingly complex nature of risks and the cascading impacts that a disaster can have across the infrastructure system. The principles support the implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030 and the Sustainable Development Goals.

A Handbook for the implementation of the Principles for Resilient Infrastructure was developed to guide on how to conceptualize, design and run infrastructure as a whole system, while implementing net resilience gain (a commitment to ensure that any interventions to infrastructure systems do not reduce infrastructure resilience). The handbook provides specific guidance tailored to different stakeholder groups (policymakers, investors, designers, contractors, etc.) and key performance indicators to monitor the progress of each intervention.

Detailed Description of the Initiative

Developing critical infrastructure with adequate capacity to cope with disasters is a fundamental aspect of improving national resilience. The integration of disaster risk management and resilience in infrastructure policies and investments is essential to ensure sustainable development of countries and communities.

Improving infrastructure resilience protects development by avoiding losses. Date from Costa Rica's National Emergency Commission (CNE) shows that in Costa Rica, direct losses in the infrastructure sector reached up to US$820 million during 2016–2020, increasing almost 266 percent from the previous five-year period. Among the actions to protect its infrastructure, Costa Rica is strengthening its critical infrastructure resilience against multiple hazards using the Principles for Resilient Infrastructure guiding framework. Costa Rica used the principles to assess the current state of critical infrastructure by identifying gaps and vulnerabilities, as well as setting priorities for action. Data from eight sectors were collected and analyzed for further action to be implemented by each sector in the short, medium and long term.

Desk research on the status of the infrastructure in eight selected sectors was complemented with interviews with representatives from the Education, Health, Electricity, Railroad, Roads and Bridges, and Postal Service sectors. Using this information, the infrastructure sectors were assessed with reference to the Principles for Resilient Infrastructure and key actions were identified with the potential to improve the resilience of the infrastructure as a system. A participatory workshop with representatives from the eight sectors built upon this analysis to share strategies, identify actions to be undertaken, and promote communication and knowledge sharing between sectors. The systemic approach underpinning the principles enabled a systemic perspective building towards initiatives already in place by some sectors and facilitated identification of potential interventions, some of them easy to implement in the short term.

Learnings and Impact

Several industry co-benefits also make themselves manifest:

- Increase awareness and understanding of resilient infrastructure across eight sectors: Electric Energy, Hydrocarbons, Roads and Bridges, Railroads, Water and Sanitation, Health, Education, and National Postal Services.
- Increase understanding of which infrastructure systems may be at risk of disruption, ranging from minor inconveniences to catastrophic failure, as well as improve the understanding of inter-dependencies among infrastructure systems.
- Resilience is mainstreamed as a core value in the planning and implementation of infrastructure projects.
- Resilience of critical services is established through compliance with standards and targets. Resilience is incorporated into policy and investment decisions with a 'think resilience' approach.
- Infrastructure is more resilient, leading to long-term savings and risk reduction.

Furthermore, the CNE expressed the intention to link this process to its yearly Risk Forum to encourage and monitor progress, as well as to promote further peer-to-peer collaboration. Overall, this process contributed to strengthening the coordination and cooperation among sectors, emphasizing the systemic nature of infrastructure in which dependencies between sectors could lead to cascading risks.

F12: Decision Support Tool for Coastal Protection for the Mekong Delta (CPMD), Viet Nam

Viet Nam

Submitted by:
GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH), Germany

Introduction to the Initiative

As part of the Integrated Coastal Management Programme (ICMP), the Decision Support Tool for Coastal Protection for the Mekong Delta (CPMD) was developed and launched in 2018 with the main objective to harmonize coastal protection planning at regional level. It is an online information system for the Mekong Delta coast with a comprehensive database and library and hosts technical guidelines for decision-making. CPMD aims to assist in the planning of coastal protection measures and prioritization of investments. Following an Integrated Coastal Management (ICM) approach characterized by cross-sectoral planning and an integration of water management, forest management, and land-use planning, CPMD considers the entire region, transcending provincial borders, and recommends targeted solutions for different parts of the coast according to their distinct local conditions.

Detailed Description of the Initiative

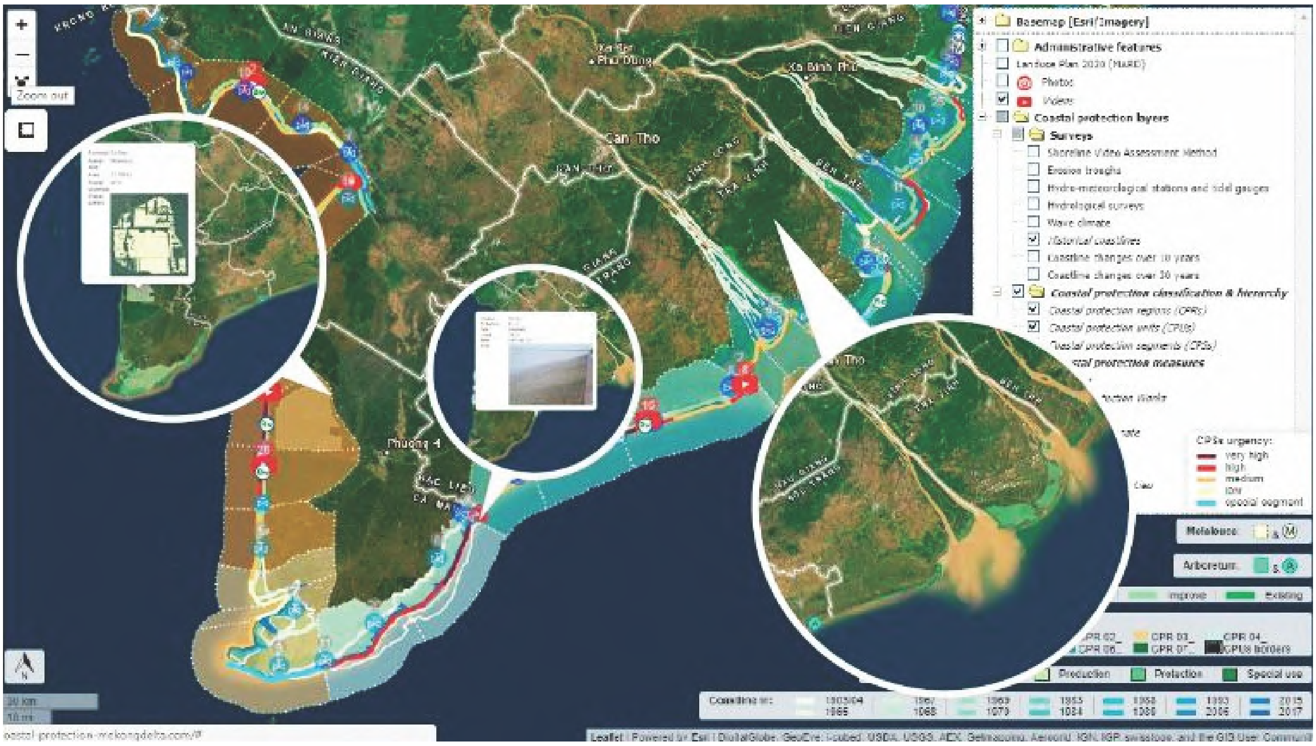
Due to climate change impacts and direct anthropogenic causes, the Mekong Delta with its key economic role, low elevation, and 17 million inhabitants, is faced with a multi-layered risk situation comprising the risk of storm surges, erosion, flooding, land subsidence, and saline water intrusion. To address these risks, the CPMD aimed to provide a baseline for decision-making to plan coastal protection measures along the coast of the Mekong Delta and the adjacent hinterland.

The tool provides, among other features, an innovative classification system of the coast, a compilation of downloadable datasets on design parameters for coastal waterworks and land use, a critical evaluation of all existing protection measures in the Mekong Delta (pros and cons), historical changes of the coastline since 1904, recommended prioritization of coastal protection measures (and rough cost estimates), and the systematic inclusion of lightweight drones (Unmanned Aerial Vehicles or UVAs) in coastal surveys. Data aggregated within the decision support tool is based on existing evidence provided by recent studies, fine-grained assessment by local experts and international consultants (from Germany, Australia, the Netherlands, and France) and the feedback of provincial government agencies under the mandate of the Ministry of Agriculture and Rural Development (MARD) and Viet Nam Disaster Management Authority (VNDMA).

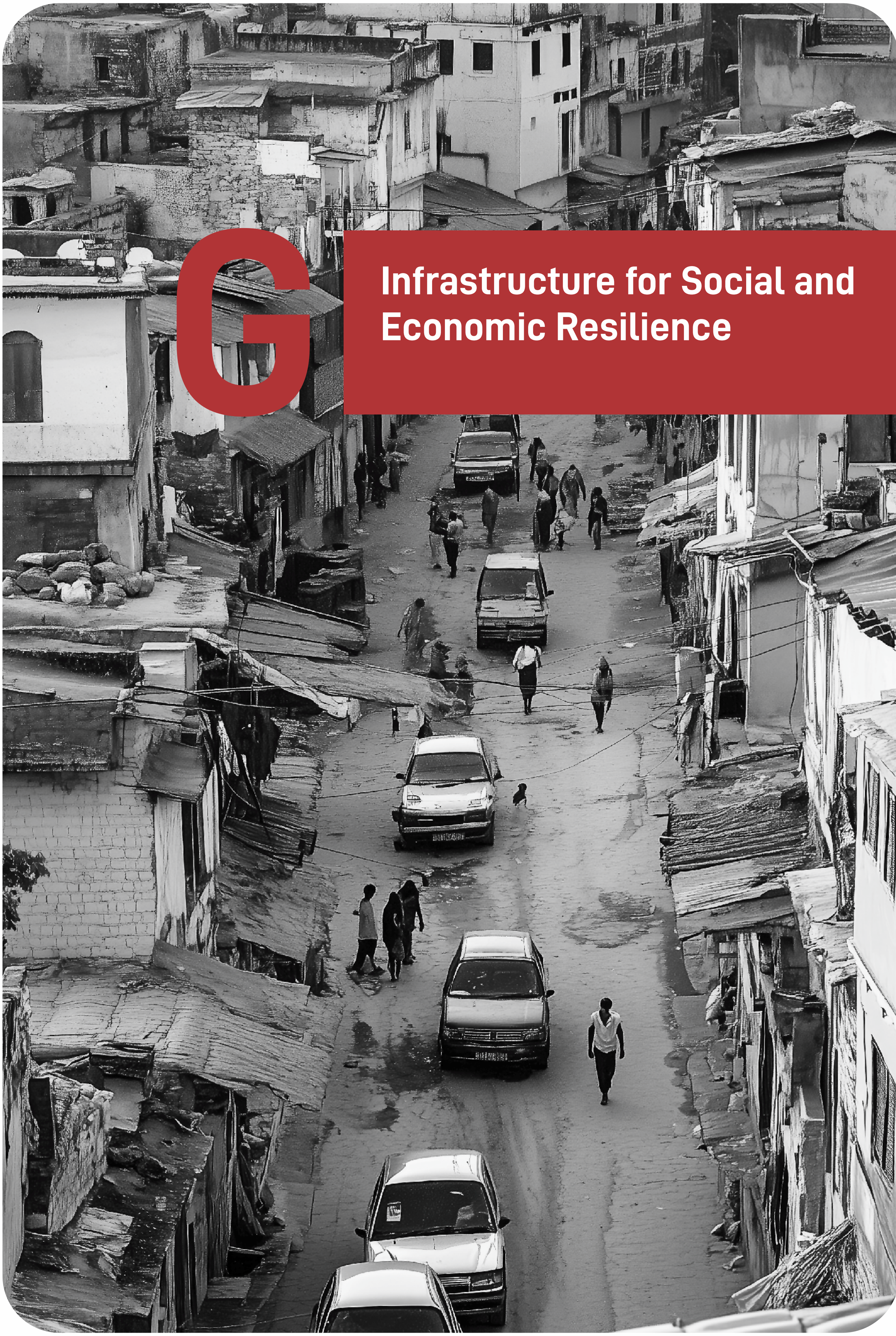
The most effective coastal protection systems consist of different elements arranged one after the other from breakwater to mangroves to a sound dyke. What is consequently needed for the Mekong Delta is a strong interlinked system of mangrove protection forest, breakwaters, sea dykes and proper land-use and water management in the hinterland. Concrete recommendations on feasible waterworks and mangrove rehabilitation for the entire 720 km of shoreline are provided. The cost estimates for direct investments in structural measures are in the order of about US$1.4 billion for the coming 10–15 years (2018–2030).

Learnings and Impact

- Mangroves provide an essential element of the coastal protection system for the Mekong Delta by shielding the coastline. In addition, mangroves considerably enhance the production of natural resources.
- A critical parameter for successful mangrove reforestation is proper site assessment. Irrigation experts, coastal engineers and forest experts need to collaborate to develop concerted rehabilitation plans.
- The involvement of local stakeholders and communities is essential.
- It is strongly recommended to institutionalize roundtables or similar formats including all coastal Mekong Delta provinces to harmonize strategies, enhance capacity and increase the efficiency of technical measures.
- The most effective coastal protection systems consist of different elements, from breakwaters to mangroves to a sound dyke, arranged according to an integrated planning framework.
- While clearly improved during the period of the CPMD development, the quality and standards of sea dyke inspection and maintenance could still be improved at the local level.
- The total cost for the reforestation of the mangroves, including the restoration of tidal mudflats and accompanying structural measures, accounts for less than 12 percent of the total cost estimated for coastal protection of the Mekong Delta and has the potential to create additional income.



User interface of the Decision Support Tool
Source: GIZ, Germany



G

Infrastructure for Social and Economic Resilience

Theme G

G: Infrastructure for Social and Economic Resilience

Infrastructure plays a pivotal role in addressing socioeconomic vulnerabilities and reducing inequalities. The seven case studies in this section demonstrate that infrastructure development can also help reduce vulnerabilities and promote equality and can have far-reaching social and economic benefits. Whether through ensuring access to essential services, mitigating environmental risks, or fostering social inclusion, these case studies provide valuable lessons on how infrastructure can be leveraged to create more resilient and equitable communities.

In Brazil, Operation Water Truck (Carro Pipa) is a key initiative that delivers potable water to isolated communities in the country's semi-arid region, helping mitigate the impacts of severe droughts. By ensuring access to clean water, this project addresses immediate needs and supports long-term health and economic stability for millions. Similarly, the Integration Program of the São Francisco River has dealt with the critical water scarcity in the northeast region by transferring a small percentage of São Francisco's water flow to smaller basins through the construction of channels and pumping stations. In this manner the initiative provides water to 12 million people in Brazil's northeast, fostering regional economic growth by enabling agricultural production and improving living conditions in historically water-stressed areas. Both initiatives illustrate how water infrastructure is essential for enhancing social and economic resilience.

In Ecuador, the Esmeraldas Pedestrian Bridge Retrofitting project focused on reinforcing a key evacuation route in a flood-prone area. This intervention not only improved community safety but also facilitated daily mobility, which is essential for economic activity and social stability. Similarly, Brazil's Slope Containment Works in Salvador, Bahia, addressed the dangers of landslides in precariously built settlements. By stabilizing slopes and improving urban infrastructure, the project reduced the risk of geological accidents during heavy rainfall, ensuring the continued residence of vulnerable families in safer, more secure environments.

The Integrated Urbanization of the Morro da Cruz Rock Massif in Brazil is a prime example of how infrastructure can tackle inequalities through comprehensive urban upgrades. This project helped informal settlements in landslide-prone areas through appropriate provision of basic sanitation, new housing units, and the creation of public spaces, directly benefiting over 5,000 families. By improving access to services and building disaster-resilient community infrastructure, the project not only enhanced living conditions but also promoted social inclusion through involvement in decision-making processes. In Vanuatu, the Haos Blong Yumi program empowers labour migrants to build climate resilient homes, fostering local ownership and resilience-building at the community level.

Infrastructure projects can extend beyond traditional sectors to include cultural spaces as part of the social safety net. The Warm Spaces Initiative at Berlin's Humboldt Forum in Germany transformed a cultural institution into a shelter for vulnerable individuals during the harsh winter months. By offering warmth, food, and advice, the museum became a refuge for homeless and isolated individuals, highlighting the potential of cultural infrastructure to address social inequalities and disaster vulnerabilities in urban settings. This initiative demonstrates how repurposing existing infrastructure can provide immediate relief to marginalized groups while promoting social cohesion and resilience.

The Slope Containment Works in Salvador and the Esmeraldas Pedestrian Bridge Retrofitting projects both involved local communities in planning and implementation, ensuring that the interventions met the specific needs of residents. By fostering local participation, these projects not only enhanced resilience but also empowered communities to take ownership of their environments. This approach to community engagement serves as a model for reducing inequalities by giving a voice to traditionally under-represented groups.

Key Takeaways

- Resilient infrastructure development that integrates social equity measures can significantly improve the quality of life for disadvantaged groups.
- Infrastructure can play a vital role in mitigating environmental risks and ensuring safety for vulnerable populations.
- Community engagement is key for building resilient infrastructure that has a social and inclusion lens.
- Repurposing existing infrastructure can provide immediate relief to marginalized groups while promoting social cohesion and resilience.

G1: Integrated urbanization of the Morro da Cruz Rock Massif in Florianópolis, Brazil

Brazil

Submitted by:
Ministry of Cities, Government of Brazil

Introduction to the Initiative

The integrated urbanization of the Morro da Cruz Rock Massif was carried out through a contract signed between Ministry of Cities and the Municipal Government of Florianópolis in State of Santa Catarina, with the transfer of resources from General Budget of the Union (OGU) and the contribution of resources by the municipal government as a counterpart. The intervention improved the quality of life of families in situations of social vulnerability, living in precarious settlements and landslide-risk areas, through integrated actions that covered socioeconomic issues, housing, environmental, land and urban infrastructure, access to public services and equipment, and disaster risk prevention aspects. The urban infrastructure developed as a part of this programme was built to be resilient towards landslides and floods so as to protect at-risk communities.

Detailed Description of the Initiative

The initiative was part of the Informal Settlements Urbanization–Growth Acceleration Program (PAC-UAP) implemented by the Ministry of Cities, which aims to support the government in raising the quality-of-life standards of families in situations of social vulnerability living in informal settlements, through the provision of urban infrastructure, improvement of housing conditions, risk reduction, provision of equipment and land regularization actions. The intervention aimed to improve living conditions in 16 communities that were home to 5,677 families, of which 438 lived in risk areas.

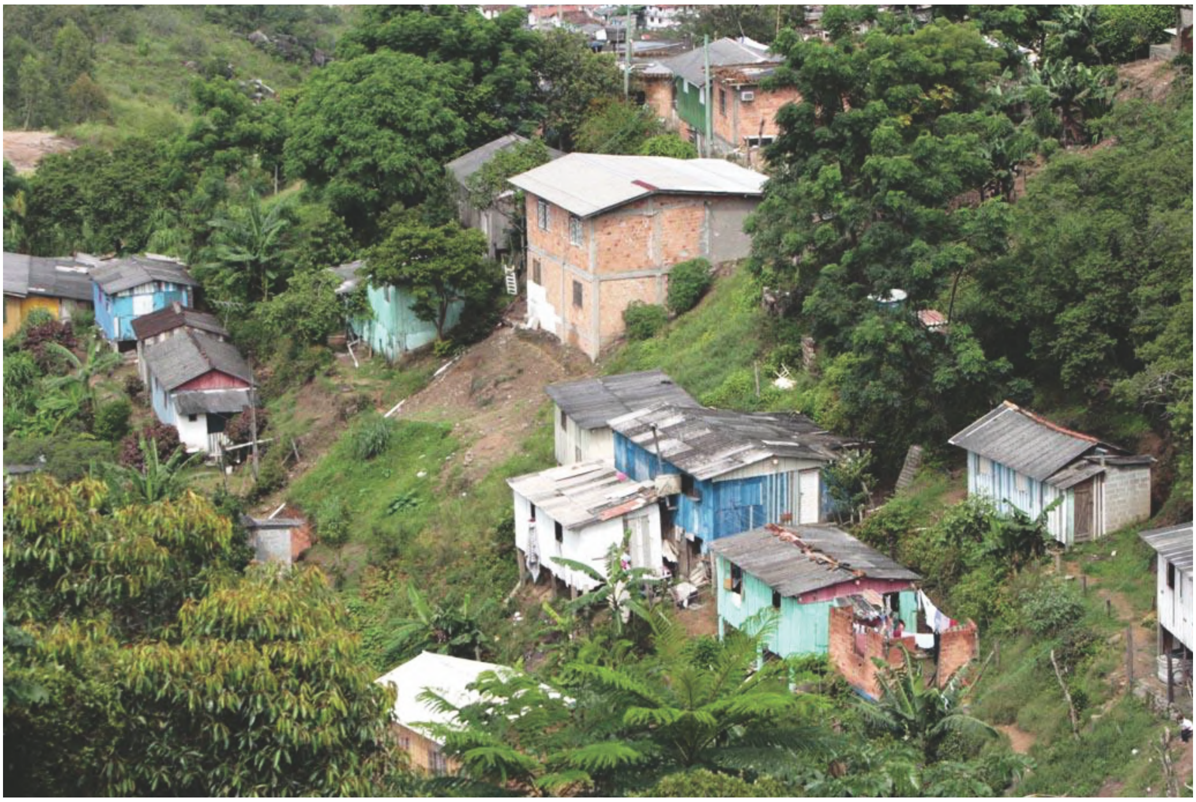
In this context, the Municipal Government of Florianópolis registered the intervention proposal in the Federal selection process of the Slum Upgrading Program, and it was selected in 2007. The total investment was US$13,068,343, of which US$8,639,897 came from the General Budget of the Union from the federal government and US$4,428,446 from the municipal government. To execute the works, the municipal government held bidding processes to hire specialized companies to implement the infrastructure and carry out the technical social work.

The projects included infrastructure works to provide access to basic sanitation, electricity and public lighting services, as well as improving accessibility conditions. Considering the existence of residences in areas susceptible to risk, on the slope of the hill, the aim was to reduce the risk of landslides and floods, allowing the consolidation of most families in the intervention area itself. For that, 45 plumbing and sanitation facilities were built, with an impact not only on improving the quality of life, but also on the hygiene and health conditions of the beneficiary families.

To assist the families that needed to be rehoused, the construction of new housing units in a nearby area was planned. Ninety-one housing units were built, in addition to ramps and stairs to improve accessibility for residents, and a public facility focused on culture.

The works included construction of a water supply network, a sewage collection network, earthmoving, paving, a rainwater drainage network, electricity supply network, installation of public lighting poles, retaining walls and soil stabilization, and environmental recovery works. A warehouse was also built in the Caiera community to sort and select solid waste with the aim of generating income for the local population. In terms of the environment, a park headquarters was built with the aim of promoting the preservation of local flora and fauna and providing sports and leisure amenities for residents.

The project also includes land regularization actions, which are currently under way, with the aim of guaranteeing possession of properties to 5,290 families. This land was originally characterized as public land and has been occupied over time. The project also included carrying out mobilization and guidance actions for the beneficiary families and monitoring throughout the implementation of the project, as well as conducting a post-intervention evaluation.



Caiera community

Structural Masonry House at Nova Descoberta Community

Modular House at Morro do Céu Community

Stone Wall at Santa Vitoria Community

Slope Containment at Caiera Community

Staircase at Monte Serra Community

Paving in Caieira Community

Drainage System at Santa Vitoria Community

Urban Resilient and Inclusive Infrastructure in different communities at risk
in Morro da Cruz Rock Massif, Florianópolis

Learnings and Impact

The two major challenges in implementation were of logistics involved in construction and negotiations for public improvements. Transporting materials in hard-to-reach locations in a rugged region with narrow alleys, and the use of machinery and equipment was impossible in many places. As the area was illegally occupied, implementing public improvements required negotiation with each resident as construction interfered with their space. This challenge was mitigated by a city-hall implemented management committee with the residents as participants. This gave them an opportunity to express their views and voices.

Meetings were held every month with the residents and local leaders from each community. The benefits of this partnership were felt in the execution of the works, improvement of the socio-environmental quality of the area, as well as the integration of the population with public agencies and public service companies to help meeting needs that were previously ignored.

These initiatives can be scaled up to other communities, given that the partnership between residents and the government brings benefits to everyone. However, the success of the partnership depends on social work and a clear understanding of the role of every individual in solving their personal and collective problems.

G2: Integration Program of São Francisco River with Basins of the Northeast Region (PISF), Brazil

Brazil

Submitted by:
Ministry of Integration and Development, Government of Brazil

Introduction to the Initiative

This project is the most important government initiative on the country's water resources agenda. It is aimed at dealing with the critical water scarcity in the northeast region by transferring a small percentage of the São Francisco river's water flow to smaller basins through built channels and pumping stations. The project is implemented by the Ministry of Regional Integration and Development.

The water transferred between the involved basins should benefit 12 million people with higher water availability in the receiving area, which covers 390 cities across four states. Higher availability of water will foster development since water stress in this region is seen as a major hindrance to economic and social change.

Detailed Description of the Initiative

The project addresses the historically low water availability in a large area in Brazil's northeast. This region has been affected by severe, recurring droughts since the nineteenth century, some of them having dramatic social and economic impacts. Given its size, impact and budget, the PISF is considered as a major initiative under the current National Water Security Plan (2019–2035).

Despite improvements in the last two or three decades, this region has been plagued with chronic economic backwardness as compared to the most developed states of the country. This is, at least partially, a consequence of low water availability and problems arising from it including limited food production, both in agriculture and livestock farming. Through the 20th century, agricultural weakness in the area led to the migration of large numbers of its inhabitants to the south of Brazil where they could find employment in low-paid jobs. Primary sector shortcomings impeded economic growth, and the region remains to this day endowed with low economic and social indicators.

Therefore, the PISF could be regarded as an economic and social turning point for the region. By alleviating water-related challenges, it is expected to make the area more appealing to economic investments, as water will no longer be a major barrier to economic activities.

The project itself is a product of long maturation. It was first conceived in the 19th century, with the initial idea emerging around 1870 and a draft presented to Emperor Dom Pedro II. However, it was only in the beginning of the 21st century that more detailed studies demonstrating the technical feasibility of this proposal, made it possible to gather support for this initiative.

Due to its high cost, the project had to be implemented through federal government resources. So far around US$2.48 billion has been invested, and about 99 percent of the physical structure has been completed. Overall, the project consists of almost 500 km of aqueducts, tunnels and channels through which water is carried from the São Francisco River to the other basins along two main axes.

Despite apprehensions about its high cost, PISF is already seen to be benefiting millions of people and it is foreseen that at its full operational capacity, northeastern Brazil, which is subject to severe drought cycles, will witness a positive change.

The challenges, nonetheless, are not limited to the physical implementation of the project and the main concern is to guarantee and maintain the economic viability of its operation. The project's maintenance cost is very high as the water needs to be pumped to a higher level, as there is a difference in altitudes. This implies higher energy consumption, accounting for around 40 percent of overall costs. This is not the only source of expense, as a wide range of equipment is also necessary to keep the continuous operation of water transfer going.

To address this issue, the Federal Government has evaluated the possibility of building a partnership with the private sector to share the costs and risks of the project. As a result, BNDES (Brazilian National Bank for Economic and Social Development) was charged with the mission to carry out studies and necessary steps to identify such partners. This process is expected to be fully implemented by December 2025.

São Francisco River Project

Learnings and Impact

PISF has faced several challenges since the kick-off of its implementation back in the 2000's. The project has faced mistrust since its inception due to its complex engineering requirements. Even after overcoming doubts about its feasibility, concerns persisted regarding financing and potential environmental impacts on the São Francisco River. In fact, along its course, the water demand has surged sharply due to irrigation agriculture, raising concerns on the project's ability to provide supplementary flows to nearby basins.

During the process of acceptance and agreement on the project's terms, it was crucial to maintain a high level of transparency and hold social discussions on its execution over the years., Further, all the environmental requirements were rigorously met, regardless of the fact that environmental agencies are also under federal governance. This in fact helped to alleviate criticism about the possible negative impacts that the transfer of water could have had on the availability of water along the riverbanks of the São Francisco River.

Despite the apprehensions and when funding was partially assured, the project commenced with the expectation of being completed within five years. However, it proved to be more complex, which was partially due to the underestimation of financial requirements, thereby progressing much slower than planned. Nonetheless, it about 75 percent of the work has been completed until now.

One of the core challenges faced by the project pertains to financial maintenance. Water policy in Brazil considers that water consumption must be paid. This is seen as a necessary measure to conserve and protect valuable resources. Accordingly, the transferred water in São Francisco basin will need to be paid for by its future users. The revenue generated should cover the costs of maintenance, serving as the cornerstone of the project's financial sustainability.

But there is no wider consensus on setting the prices and whether there should be distinct prices for each sector (agriculture, industry, householders). Even if the project benefits society at large, the distribution of the financial burden may be disproportionate among different user groups and provoke some stress among managers. In brief, such a project is also highly dependent on a kind of political negotiation with stakeholders and society.

The initiative can be expanded to increase the amount of water to be transferred and benefit still more people and cities. However, this will depend on future availability and, more importantly, funding. In that sense, the project has been designed in a manner that allows this upgrade to be carried out without major difficulties.

Additional Information

Video Link

Ministério da Integração Desenvolvimento Regional. (2024). Projeto de Integração do Rio São Francisco (PISF). YouTube. https://www.youtube.com/watch?v=XYQ2LRM25-k

Readings

São Francisco Project Website. https://www.gov.br/mdr/pt-br/assuntos/seguranca-hidrica/projeto-sao-francisco

G3: Slope Containment Works in Salvador, Brazil

Brazil

Submitted by:
Ministry of Cities, Government of Brazil

Introduction to the Initiative

The slope containment works, part of the Growth Acceleration Program (PAC), aimed to provide security for homes, families and vulnerable people living in landslide-prone areas. This initiative in Salvador, Bahia involved an integrated effort between the federal government and the state government of Bahia, through its Urban Development Company (CONDER).

The area of the intervention was characterized by disorganized occupation of slopes, deforestation, inadequate cuts and fills, and uncontrolled discharge of sewage and wastewater. Between 2021 and 2015, Salvador's Civil Defence received numerous emergency requests related to threats of building collapses, landslides, and falling trees in the area.

Beyond the infrastructure measures, the interventions prioritized respecting the social aspects of the urban environment and community relations, equipping cities with multifunctional projects.

Detailed Description of the Initiative

Since 2004, Salvador has had a Slope Master Plan (PDE in Portuguese) identifying 437 risk areas, 93 of which were classified as Very High Risk. Based on the diagnosis of the geological and urban conditions in the region, the government of Bahia entered into an agreement with the federal government in 2012 for the execution of slope containment works at 102 sites, costing US$29 million.

One of the highlighted projects within this program was PDE 124, which received an investment of US$2 million. The work for this project were carried out on four specific streets: Padre Norberto Rodrigues, Ana Piedade, Adonias Ferreira and Maria Amaral. The interventions included various engineering solutions for soil containment and protection, such as soil nailing, protection on rocky soil, anchor walls, paving and drainage.

In addition to the containment works, additional investments were made to enhance local infrastructure. This included the installation of a volleyball court, a soccer field, a jogging track, a community area, a children's playground, and fitness equipment. These urban amenities complemented the basic infrastructure of mobility and safety but also contributed to community leisure.

The stabilization of slopes and improvement of surrounding infrastructure helped ensure the safety of families living in the affected areas, creating a more stable and secure environment, especially during intense rainfall periods that previously posed risks of geological accidents. The intervention contributed to the continued residence of families in their homes, reducing vulnerability to disasters and enhancing the local quality of life.

Slope Containment and Informal Settlement Urbanization at PDE 124

Slope Containment and Informal Settlement Urbanization at PDE 124

Learnings and Impact

The multifunctional projects carried out through slope containment works, such as PDE 124, have increasingly contributed to reducing vulnerabilities in various neighbourhoods of Salvador. From a normative and reference standpoint, the project aligns with municipal planning and is implemented at the neighborhood and local community level. Besides the tangible aspects of the construction, the physical intervention yields subjective benefits, impacting mental health and fostering a sense of well-being and security among residents.

A key challenge was reconciling physical and social project elements, particularly avoiding involuntary relocations. Relocations were considered only as a last resort when there was no technically feasible way to ensure safe continued residence.

Another key aspect was effective communication and engagement with affected families. Addressing sensitive issues and changes in people's lives required a dialogical effort to resolve disagreements or communication breakdowns, especially concerning the temporary and permanent relocation of families for project implementation. Regular community meetings, mobilization, and socio-educational actions were employed to ensure smooth and effective communication and participation.

Whenever possible, local residents were hired as construction workers. This addressed the labor needs required for the project and helped unemployed workers re-enter the job market, contributing indirectly to socioeconomic change in the neighbourhood.

Attention was also given to strengthening and reorganizing community leadership and established organizations. These stakeholders were involved in actions that were part of the project's execution and social and technical scope. Encouraging and legitimizing local community leadership facilitated engagement and social participation, allowing CONDER to rely on local partnerships for essential mobilizations and guidance throughout the intervention.

The intervention directly and indirectly benefited 2,363 residents. To achieve the project's goals, US$45,000 was allocated for compensation payments, benefiting 10 families. Over the four years of intervention, U$$78,000 was spent on provisional social rent for families. Other beneficiaries included construction workers (mainly locals) and the technical team executing the intervention (designers, geologists, surveyors, drillers, engineers and social workers, among others).

Initial approaches and ongoing communication with beneficiaries highlighted the need to address structural changes when temporary and permanent relocations were necessary for project implementation. Another issue was dissatisfaction with the compensation amount and rental assistance.

Through socio-educational actions with families, the project fostered community mobilization and organization. This engagement drove changes in attitudes towards the environment, heritage, and healthy living, reflecting the transformation brought about by the new landscape.

G4: Operation Water Truck, Brazil

Brazil

Submitted by:
Department of Civil Protection, Government of Brazil

Introduction to the Initiative

The Carro Pipa (Water Truck) Operation is an emergency initiative of the Brazilian federal government which is aimed at providing potable water primarily to rural and isolated communities in the Brazilian semi-arid region. These communities are severely impacted by droughts and water shortages. Coordinated by the National Secretariat for Protection and Civil Defense (SEDEC), with support from the Brazilian army, the operation deploys water trucks to transport water from pre-selected sources. This initiative is being undertaken to alleviate the water scarcity in these regions until the São Francisco River Transposition Project is under construction. This coordinated response is crucial in addressing the growing challenges and aiding affected communities, particularly during a time when the drought situation is being exacerbated by climate change. This initiative enhances resilience of these communities towards drought and builds on disaster risk reduction (DRR) principles.

Detailed Description of the Initiative

The Brazilian semi-arid region, spanning nine northeastern states and northern Minas Gerais, covers 12 percent of the national territory and is home to approximately 28 million people, making it one of the most densely populated semi-arid regions in the world. Characterized by irregular rainfall and high evapotranspiration rates, this region is highly vulnerable to water scarcity. Additionally, it is prone to torrential monsoons which tend to cause severe flooding within short periods. With increasingly prolonged droughts, exacerbated by climate change, it has become critical to implement emergency solutions to ensure access to potable water, prevent sanitary crises, and safeguard the survival of the most vulnerable populations.

Operation Carro Pipa (OCP) was designed as an urgent response to this need, with the primary goal of providing regular and safe water supply to affected communities, mitigating the impacts of drought, and strengthening the region's resilience. Building water infrastructure in the semi-arid region is a monumental challenge due to inconsistent rainfall, long dry periods, and high evaporation rates that undermine the effectiveness of reservoirs and water storage. The vast territorial expanse and dispersed communities render centralized systems impractical. While the São Francisco River Integration Project is underway to ensure water security for around 12 million people, it is essential to enhance the resilience of the population to address recurring hazards.

This initiative is being Implemented as an emergency action and is coordinated by the federal government through the National Secretariat of Protection and Civil Defense (SEDEC), with crucial support from the Brazilian army. Operation Carro Pipa involves several key steps. These include careful selection of safe water sources, efficient water transportation via trucks, and optimized distribution routes. The operation also benefits from cooperation with state and municipal governments, providing local support and facilitating community coordination.

OCP primarily focuses on the water supply and sanitation sector, but it also intersects with the civil defence and public health sectors, preventing waterborne diseases linked to contaminated water. The initiative has significant social implications by promoting community stability, preventing rural exodus, and improving regional infrastructure. Therefore, Operation Carro Pipa is a multifaceted initiative that spans and interacts with critical sectors essential for the well-being and resilience of the communities of the semi-arid region.

The operation has ensured continuous water supply to millions, preventing diseases related to contaminated water and reducing water vulnerability, thus contributing to a decrease in infant mortality. Additionally, it has fostered a more inclusive and resilient recovery, enhancing communities' ability to withstand future water crises and improving their living conditions. OCP has played a pivotal role in reducing vulnerabilities and inequalities, ensuring that the most isolated and disadvantaged communities receive the same level of emergency support as more accessible areas, thereby contributing to equitable water resource distribution and strengthening community resilience.

Filling water in a tank

Learnings and Impact

During the implementation of Operation Carro Pipa, several challenges required strategic approaches. The logistical complexity of the operation, due to the vast territorial extension of Brazil's semi-arid region and the dispersion of communities, was one of the main obstacles. To address this, detailed logistical plans were developed, utilizing mapping technologies and optimizing transport routes to ensure that water reached the neediest areas quickly.

Another significant challenge was the coordination between the various entities involved, such as SEDEC and the Brazilian army. Initially, communication difficulties and unclear responsibilities posed obstacles, but these were overcome by establishing clearer cooperation protocols and holding frequent meetings, which improved the integration of activities and sped up emergency responses. Additionally, the lack of adequate infrastructure and the need for strict monitoring were addressed through the installation and maintenance of water distribution points, road preservation, and regular audits. Community engagement through awareness campaigns was also essential in fostering acceptance and facilitating the operation's execution.

OCP generated significant co-benefits, such as the empowerment of local communities, which began to take a more active role in promoting autonomy and resilience. The operation also spurred improvements in regional infrastructure, such as road maintenance and the establishment of water distribution points, providing long-term benefits to the communities. For the institutions involved, including SEDEC and the Brazilian army, the operation enhanced their coordination and emergency response capabilities, establishing an efficient model that can be replicated in future crisis situations.

To scale OCP effectively and sustainably, it is necessary to invest in several areas. Infrastructure is a priority, including the expansion of the truck fleet and the construction of additional water distribution points and reservoirs to increase storage capacity and improve operational efficiency. Strategic partnerships with the private sector, NGOs, and local governments are essential to share resources, knowledge, and technical, financial and logistical support. Moreover, capacity building and training of the institutions involved, such as SEDEC, are critical for strengthening crisis management, logistics, and the use of innovative technologies, such as rainwater harvesting, to complement water supply in more remote areas.

To ensure the sustainability of the operation on a larger scale, it is important to diversify funding sources, seeking support from government funds, private donations, and public-private partnerships. Implementing rigorous financial management practices, communication strategies, and community engagement are vital for the ongoing success of the operation.

Additional Information

Readings

Project Website. https://sedec.5cta.eb.mil.br/.

Ministry of Integration and Regional Development. (2024). Operation Carro-Pipa: more than 16.4 million people received drinking water in their homes in 2023. https://www.gov.br/mdr/pt-br/noticias/operacao-carro-pipa-mais-de-16-4-milhoes-de-pessoas-receberam-agua-potavel-em-suas-casas-em-2023.

G5: "Warm spaces" – Supporting Vulnerable Groups in the Humboldt Forum Museum, Germany

Germany

Submitted by:
German Federal Foreign Office, Government of Germany

Introduction to the Initiative

One of Berlin's most iconic museums, Humboldt Forum, has opened its doors during the winter months for the past two years to provide a welcoming and warm space for people in need. Anyone is welcome to come in to escape the harsh winter cold, receive a hot drink and a snack, and get free advice if they need it. The museum also provides an area with books and donated items. In this way, the museum is fulfilling its role as part of the cultural infrastructure to help the most vulnerable members of society.

Detailed Description of the Initiative

Poor people in particular are faced with rising heating and energy costs. In addition, the climate crisis means that extreme weather situations are likely to occur more frequently. People without a permanent home or with inadequate heating are particularly exposed to this. In view of these social challenges, cultural institutions and stakeholders must also reflect on their responsibility in this situation. Could museums, for example, become a so-called "third space" in which people in need can find refuge? In Berlin, where it may be below zero in the winter months, a project is trying to counter this with a "place of warmth".

Humboldt Forum is one of Berlin's most important museums, with exhibitions on the history of the site and Ethnological and Asian Art collections. Its owner and operator is the Humboldt Forum Foundation. In cooperation with Johanniter, one of the largest Christian providers of health and care services, and the museum's shop, the foundation has opened its doors to all Berliners – including the most vulnerable groups – to provide a warm place to spend the day in winter, a snack and a hot drink, advice and, above all, shelter and comfort. The museum also offers an indoor area with books and donated items.

Learnings and Impact

The focus of the initiative is not on saving lives but on offering a safe and warm place for disadvantaged and vulnerable people within the urban community. Therefore, "Place of Warmth" is not only open to homeless people but also, for example, to elderly individuals who suffer from loneliness. The museum also hosted an exhibition of portraits and stories of homeless people in the space, giving visibility and dignity to people who are too often marginalized in our society.

In the winter of 2022/2023, almost 10,000 people used the space – around 150 people a day on cold days. The project is open to anyone who wishes to visit the museum and has also benefited visitors to the museum's exhibitions. This service is also made possible by Johanniter volunteers who look after the museum's guests.

Humboldt Forum Foundation is funded by the Federal Government Commissioner for Culture and the Media. The costs and effort involved in the initiative are low. This is partly because "Place of Warmth" has been integrated into the existing infrastructure of Humboldt Forum, and partly because it has been sponsored by donations from Johanniter, employees of Humboldt Forum, as well as other charitable organizations in Berlin and/or food companies and distribution centres.

G6: Esmeraldas Pedestrian Bridge Retrofitting, Ecuador

Ecuador

Submitted by:
Development Bank of Latin America and the Caribbean (CAF)

Introduction to the Initiative

A project for structural reinforcement of a pedestrian bridge was implemented in Esmeraldas city under the AdaptaClima project. The project focused on structural reinforcement of a pedestrian bridge connecting Roberto Luis Cervantes Island to the mainland. This project is part of an early warning system for flooding. The project is implemented by the Ministry of Environment, Water and Ecological Transition (MAATE) with support from CAF as the implementing entity and UNDP as the executing entity. The reinforced bridge now serves as a critical evacuation route, significantly improving community safety during floods. This initiative is a good practice due to its comprehensive approach to disaster risk reduction and climate adaptation, ensuring community involvement and resilience of community infrastructure. The budget for the project was US$60,440.

Detailed Description of the Initiative

The need for this initiative arose from increasing concerns about the structural integrity of the bridge, as it is one of the main evacuation routes for the residents of Roberto Luis Cervantes and Luis Vargas Torres islands in the event of flooding. Therefore, the reinforcement of the bridge was carried out as an integral part of an early warning system for floods which was also implemented in this area. Over time, the bridge was showing signs of wear and tear, raising fears of potential failures that could endanger lives. The initiative aimed to address these vulnerabilities by strengthening the bridge structure to ensure its long-term stability and safety.

This initiative had the support and coordination of Public Works Department of the municipality of Esmeraldas. A construction company was contracted to implement the works and a supervisor was hired to ensure the quality of the work. The community was also involved to ensure that the project met the needs of the local population.

The following actions was taken:

- **Assessment and Planning:** A comprehensive assessment of the bridge's current condition was conducted, identifying key areas that required reinforcement. Detailed plans were developed, outlining the specific reinforcement techniques. Final engineering designs for the bridge were created.
- **Reinforcement Work:** The actual reinforcement work involved the installation of additional support structures, the application of advanced materials to strengthen existing components, and the implementation of modern engineering techniques to enhance the bridge's overall resilience.
- **Monitoring and Evaluation:** Throughout the project, continuous monitoring was conducted to ensure that the reinforcement work was proceeding as planned and was also meeting safety standards.

The pedestrian bridge on Roberto Luis Cervantes Island connects the island with the mainland

The rehabilitated pedestrian bridge benefits about 630 inhabitants of the island.

Learnings and Impact

A primary challenge faced during the construction was overcoming the security issues around the area, which caused several delays. To mitigate this, the team worked directly and closely with the community leaders to ensure the safety of the workers. This collaboration was crucial in creating a secure environment for the project to proceed. Additionally, adjustments to the final designs had to be made on the site, which were addressed promptly to avoid significant disruptions.

This initiative significantly contributed to reducing vulnerabilities and inequalities in several ways:

- **Enhanced Safety:** By reinforcing the bridge, the initiative ensured the safety of thousands of daily commuters,reducing the risk of accidents and potential fatalities.
- **Economic Stability:** The improved bridge infrastructure facilitated uninterrupted mobilization, which is vital for local businesses and the economy. This stability helps in reducing economic disparities by supporting local commerce and trade.
- **Community Confidence:** The successful completion of the project boosted the community's confidence in local infrastructure projects, fostering a sense of security and well-being among residents.
- **Inclusive Planning:** The involvement of community organizations in the planning and implementation phases ensured that the project addressed the needs of all community members, including vulnerable populations. This inclusive approach helped in reducing inequalities by giving a voice to those who are often underrepresented in such initiatives.

The initiative is highly scalable. The approach of working closely with community leaders to ensure security and the flexibility to make design adjustments as needed can be applied to similar infrastructure projects in other regions. The successful strategies and lessons learned from this project can serve as a model for future projects. Moving forward, it is essential to continue fostering strong relationships with community leaders and organizations to ensure the success of future projects. Additionally, incorporating flexibility in project designs and plans will allow for timely adjustments and improvements, ensuring that projects can adapt to unforeseen challenges.

Additional Information

Additional Information

Video Links

PNUD Ecuador. (2024). Puente peatonal rehabilitado en la isla Roberto L. Cervantes. Informational video about the inauguration of the pedestrian bridge. YouTube. https://youtu.be/I_vuTXo_e9s

Testimony 1 of one of the bridge beneficiaries: https://youtu.be/hzC6ou3fWTk

Testimony 2 of one of the bridge beneficiaries: https://youtu.be/J-b8i0UUnrg

G7: Turning the Opportunity of Overseas Work into Disaster and Climate-Resilient Housing, Republic of Vanuatu

Republic of Vanuatu

Submitted by:
Department of Foreign Affairs and Trade, Government of Australia

Introduction to the Initiative

Vanuatu is one of the most at risk (multi-hazard) countries in the world when it comes to disasters and climate change impacts. It is prone to tropical cyclones, storm surges, landslides, flooding, droughts, volcanic eruptions, earthquakes and tsunamis. Cyclone Harold (2020) destroyed or damaged nearly 21,000 houses and severely affected 55,000 households. In the last three years alone, Vanuatu has been hit by five major cyclones, with devastating impacts felt throughout the country. Because of this, building cyclone-safe and disaster-resistant housing is a top priority for many families. The government has formulated various plans and policies to tackle the impacts of climate change and natural hazards and build a resilient nation.

The Vanuatu Labour Mobility Program is a significant opportunity for the citizens of Vanuatu to work abroad to earn and save more money. The program sends workers from all around Vanuatu to work in New Zealand and Australia to earn, save and develop new skills, predominantly in the agriculture and tourism sectors. Building or improving a home is often one of the top priorities of overseas seasonal workers. The remittances and savings they can make abroad provide a catalyst for this. To ensure returned workers are building climate resilient housing that can withstand disasters, Haos Blong Yumi reintegration workshops equip returned workers and their families with essential knowledge on managing building projects, saving, and building modern, disaster resilient homes. The process and products (resilient houses) of this program would be an important component of the compendium.

Detailed Description of the Initiative

Saving and investing the economic rewards of overseas work into disaster resilient housing has multiple benefits for workers, their families and communities. Jointly facilitated by World Vision Vanuatu[24] and supported by the Vanuatu Department of Labour, Haos Blong Yumi reintegration workshops are targeted towards returned labour mobility workers and their spouses. The reintegration trainings teach recently returned labour mobility workers how to manage small building projects with savings they have earned overseas. The workshops cover a wide range of topics, such as understanding the scope of a building project, project design, choosing a location, disaster risk management, budgeting and managing finances.

Haos Blong Yumi reintegration program complements World Vision and International Organization for Migration's Famili I Redi program,[25] a pre-departure workshop for labour migrants and their spouses. Together with World Vision's one-day Haos Blong Yumi pre-departure short course, the programs encourage overseas workers to start thinking and planning for their house building project well before they depart on their labour mobility journey. Between 2021 to 2023, ten Haos Blong Yumi workshops were successfully conducted in Sanma province with a total of 261 participants, including 115 women.

More than 40 percent of the housing stock in Vanuatu is of traditional type. There is an opportunity to investigate traditional construction techniques and designs with local builders and tradespersons and reintegrate them into the present-day situation. The compendium would contain improved traditional housing types with improved structural safety and durability as per the building safety codes of Vanuatu. The compendium would capture those housing types that survived the past cyclones.

Haos Blong Yumi was supported through the Australian Humanitarian Partnership (AHP) COVID-19 activation, funded by the Australian government. It was then continued through the AHP's long-term recovery response to Tropical Cyclone Harold. The program will continue to be implemented in Torba and Sanma provinces under the five-year AHP Disaster READY program.[26]

Greg, a returned overseas worker, and his wife sharing their story with World Vision Vanuatu staff
Source: World Vision Vanuatu

The house that Greg built after attending the Haos Blong Yumi reintegration workshop
Source: World Vision Vanuatu

[24] World Vision Vanuatu is an NGO based in Vanuatu, connected to World Vision's international NGO network and a member of the Australian Humanitarian Partnership. The Department of Labour is the government of Vanuatu department responsible for facilitating labour mobility programs.

[25] Famili I Redi is a pre-departure workshop for labour migrants and their spouses, run by World Vision Vanuatu, the International Organization for Migration, and the Vanuatu Department of Labour. The workshop aims to maximise the socioeconomic benefits of labour mobility for workers, reduce the risk of gender-based violence, and support strong and equitable partnerships and relationships while a family member is working abroad.

[26] The Disaster READY program is a 10-year $100 million AUD disaster risk reduction, preparedness and climate change adaptation program funded by the Australian Government. It operates in five countries: Vanuatu, Papua New Guinea, Solomon Islands, Timor-Leste and Fiji. It is implemented through the Australian Humanitarian Partnership, a partnership of six leading Australian NGOs and their in-country partners.

Testimonials: Greg, Pierre and Sandy

Greg's story

Greg Charlie and his family live in the outskirts of Luganville town on Santo Island in Vanuatu, in a neighbourhood called Side River, located along the country's second largest river, the Sarakata. Greg, his wife and son lived with his parents in their house for a few years. Living with family comes with lots of benefits including child and financial support, as well as shared responsibilities. It had always been Greg's dream to build a separate house for his small family of three to live in and call their own.

Greg joined Vanuatu Labour Mobility Program to find a better paid job and earn more money. Greg worked on a farm in Australia for seven months on a contract basis and travelled back and forth to Vanuatu every few months.

"The workshop taught us how to organize, scope and plan a housing project with the correct budget. This includes considering the location and disaster risk management side of things when building a house," Greg said.

"The biggest benefit I can see for our family is I can now support my wife in managing our family budget, so we can complete building our house."

"I have gained a lot of new ideas from the Haos Blong Yumi trainings, and it has made positive changes to my family's living standard," Greg said.

Greg has now accomplished his goal of building a new house for his small family from the things he learned in the workshop. The workshop has also given him ideas about future building projects.

"I encourage [labour mobility scheme] workers to attend these types of workshops and trainings as it can make a real change to their lives," he concluded.

Pierre's story

Pierre Talo lives with his family in Natawa village on the east coast of Santo, the second-largest island in Vanuatu's archipelago and home to some of the country's most popular tourist destinations.

While life on Santo comes with many benefits, like safer and healthier lifestyles, communal living, and lower living costs from subsistence farming and renewable energy, communities are still grappling with the increasing impacts of disasters and climate change.

"I know that going into the future our environment will change drastically, and there is a need to build cyclone-safe houses," said Pierre.

Pierre's sons joined the Vanuatu Labour Mobility Program to earn and save more money. His sons worked on farms in Australia for seven months on a contract basis and travelled back and forth to Santo.

"Both my sons have no family of their own yet and used to live with my wife and I in the main house. They decided to travel and work overseas to save up and build their own houses, because it costs more to build stronger houses compared to traditional houses. When they travelled, I became the project manager and managed all the building logistics for them on ground," Pierre said.

"The benefit of living in rural east coast Santo is that materials can be easily sourced from nature to start building, including labour, because we live in a community."

Pierre attended the Haos Blong Yumi workshop in October 2022 at Natawa Community Centre.

The program focuses on practical skills to equip returning workers and their families with the knowledge they need to successfully manage small building projects.

"I learned new ways of building a strong house, how to budget and manage finances when purchasing materials, and managing logistics and construction. Most importantly, ways of how I can effectively communicate and support my boys with this building project," he said.

"It brings me comfort and happiness knowing that my sons and future grandchildren will live in a cyclone-safe house, or houses that can withstand disasters. I highly recommend this workshop to other [labour mobility] scheme workers. It will change your mindset and build your knowledge, and help you manage your homes."

For Pierre, the training also opened his eyes to exciting possibilities for his family.

"I had a very fixed mindset about life before attending the workshop and now I realise life can be better. Supporting my boys is my number one priority and I can help change their lives for the better," Pierre said.

Sandy's story

Home to beautiful white sandy beaches, crystal blue water and lush green forests, Teproma village is located along the southeast coast of Santo Island, just a few minutes' drive from Pekoa International Airport and Luganville town in Vanuatu. Sandy Antas, his wife Lindy and their four kids live in the village with their immediate and extended families.

Village life in Teproma has changed dramatically over the years with an increased number of natural disasters, greater demand for secondary and tertiary education, and changes from traditional to modern lifestyles. All these things come at a higher cost.

"I wanted to travel for work overseas through the mobility program so that I could earn more money to provide for my big family and build our own house," said Sandy.

"We used to live with my parents in their house before building our own house."

Sandy has not travelled overseas for work yet due to his current work and family commitments but plans to do so in the future. He was fortunate to be part of the Haos Blong Yumi workshop in October 2021, at the Maritime College in Luganville.

Before attending the workshop, Sandy had no prior experience constructing a house, but he now uses his skills and knowledge to work in the field of construction.

"Since attending the workshop I have built three houses in total. One of the houses is full concrete with three rooms, a living room, kitchen, storage room and a veranda. I have also learnt to manage my family's finances and everyday activities as well."

"Life was a bit difficult in the past because we did not know where or how to start work on our house," said Lindy, Sandy's wife. "The major change came after we attended the Haos Blong Yumi workshop because things have become more clear and easier."

"Our future is better now knowing our children are living in a house that is safe and disaster resilient," she said.

"This workshop is crucial for workers in the Vanuatu Labour Mobility program planning to build a house for their family. It is important they know how to build houses that can also withstand natural disasters," Sandy added.

Learnings and Impact

Enablers and barriers

Populations affected by severe Tropical Cyclone Harold (notably former overseas workers in Sanma province) were closely involved in the development and design of training curricula through participation in focus group discussions.

Tropical Cyclones Judy and Kevin affected workshop delivery. Catch-up workshops meant that the program was still able to reach its participant targets. However, household financial reprioritization due to the disasters meant fewer participants were able to implement their learnings. Only 48 percent of participants in 2023 were able to apply their learning to new building projects or home upgrades, compared to 58 percent in 2021.

The Haos Blong Yumi curriculum was modified to include a module focusing on the considerations of people with disabilities to be delivered to all HBY participants, rather than only delivered to participants with a household that currently includes a person with a disability. This decision was taken in consultation with World Vision's Inclusion Technical Advisor with the intention to raise awareness of all participants about the needs of people with disabilities and in recognition of the fact that as people age and/or are affected by health issues, increasing knowledge and awareness of inclusion of people with disabilities may help "future proof" a house to enable access by a person with an acquired disability later in life. Piloting of the revised inclusion module took place in January 2023. Four inclusive Haos Blong Yumi workshops were conducted with returned overseas workers during the final six months of the project, supporting 302 people.

An unexpected outcome of the Haos Blong Yumi (HBY) training was that a number of partners of overseas workers opted to attend the training (accompanied by a trusted family member) whilst their spouse was overseas. The partner then relayed the learning from the day to their overseas spouse during evening calls and some building projects commenced whilst the couples were still apart. Sometimes the project was managed by the female partner who attended the HBY training in person.

Key Takeaways

By bringing together multiple key stakeholders, working with the government, and capturing the needs and aspirations of returning overseas workers, Haos Blong Yumi provides a model for other remittance-receiving countries to consider increasing the availability of disaster and climate resilient housing, while empowering communities and individuals to work towards their own personal and family goals.

While there are existing guidelines and manuals on safer construction in the Pacific region, there is a need for a compendium of resilient housing relevant for the socioeconomic and cultural context of Vanuatu.

G8: Periferia Viva: Improving Living Conditions and Resilience of Peripheral Informal Settlements, Brazil

Brazil

Submitted by:
Ministry of Cities, Government of Brazil

Introduction to the Initiative

Periferia Viva (Living Periphery) Programme is an initiative by the Brazilian government which is being undertaken through the National Secretariat for Peripheries of the Ministry of Cities. Its goal is to promote the execution of integrated actions in urban peripheral settlements to enhance their access to public goods and services. This will improve their living conditions and accelerate social and economic inclusion. Under the purview and guidance of the Civil House of the Presidency of the Republic and the Ministry of Cities, the programme enables coordinated action by various federal government agencies in Brazil.

The impact of Periferia Viva is on peripheral territories as it addresses their vulnerabilities through a coordinated governance model which includes government agencies on both national and territorial levels. The programme ensures their physical presence in the peripheral territories through small offices or "Territorial Posts". This presence is crucial for providing technical advisory and local action planning.

Periferia Viva is considered a good practice in addressing urban and social issues by adopting innovative and adaptable public policies for housing and infrastructure to improve local resilience, and implement them through coordinated action.

Detailed Description of the Initiative

Peripheral settlements across Brazil are characterized by urban, racial, territorial, and social segregation. They lack fundamental urban rights such as decent housing, sanitation and mobility. They are disproportionately affected by extreme climate events – a situation referred to as "climate injustice." According to the Brazilian Institute of Geography and Statistics (IBGE), 5.12 million households live in substandard clusters, and 24.4 million households face infrastructure deficiencies or land tenure issues.

Periferia Viva consists of four major areas for action. The first is the provision of urban and environmental infrastructure in vulnerable settlements. The second is social public services, which include construction or refurbishment of community facilities. The third is social and community strengthening, which includes actions to improve access towards social rights, enhance collaborations and support ongoing community initiatives. The fourth area is innovation and includes technology and opportunities to undertake actions for professional and technological training and encouraging a creative economy.

The programme focuses on the urban and housing sector – particularly in informal settlements like "favelas" – and other complementary government actions. Urban infrastructure actions incorporate investment in basic sanitation (water, sewage, drainage, solid waste management), electricity supply and streetlighting, urban mobility and accessibility, construction of new housing and improvements, community amenities and regularization of land, and infrastructure to reduce disaster risk reduction as floods and landslides. It also promotes environmental recovery and utilization of nature-based solutions (NbS).

Periferia Viva is implemented through a two-tier governance structure. There is a National Interministerial Steering Committee at the national level and a territorial post in each programme territory. The territorial post in provides technical advice and develops action plans. The programme is supported by various organizations, such as Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Fundação Tide Setúbal, United Nations University–Institute for Environment and Human Security (UNU-EHS), the International University of Peripheries (UNIperiferias), UNICEF, and World Resources Institute Brazil.

The territorial post also anchors other territorial agents such as public authorities for issuing technical advisories. Technical advisories are developed through a participatory process. The territorial post also prepares an Action Plan to conceive territorial planning, including environmental and urbanization interventions, taking into consideration a broad set of other sectoral policies of the federal government. All engineering, urban planning and architectural projects towards programme actions are undertaken according to this plan.

The program also includes risk prevention and mitigation actions. It has also established an award called the Periferia Viva Prize to recognize initiatives that tackle socio-spatial inequality and enhance peripheral territories. In 2024, 59 peripheral territories were selected for investment, totalling approximately US$1 billion. Since 2023, new programme guidelines have been adopted to resume 85 old infrastructure contracts for providing urban infrastructure in favelas. A new selection process for proposals was also implemented within states and municipalities. A total of 59 proposals from 48 different municipalities were selected across Brazil, totalling US$1 billion in federal investments. Among these new proposals, 37 included investments in environmental recovery actions, 33 in risk reduction actions, and 28 in NbS.

Contribution to Reduce Vulnerabilities and Inequalities

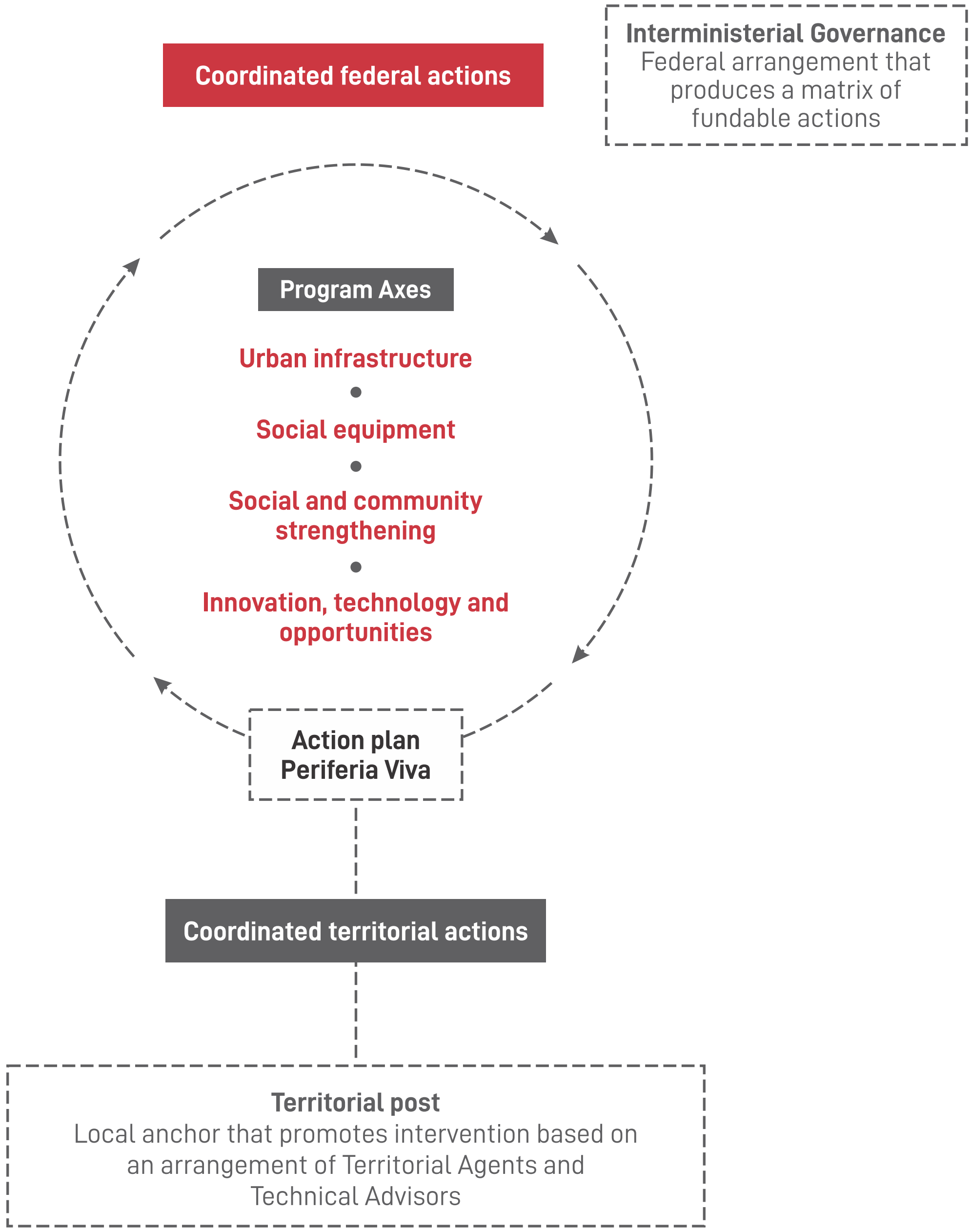
The Periferia Viva programme addresses the multifaceted needs of peripheral settlements by integrating urban infrastructure improvements with efforts to enhance living conditions and access to services. It also acknowledges the resilience and potential of these territories, supporting initiatives that promote local self-management and advocacy.

A concrete example of the implementation of the programme is the integrated urbanization of the Morro da Cruz Rock Massif in Florianópolis, Santa Catarina. The intervention aimed to improve living conditions in 16 communities, where 5,677 families lived, of which 438 lived in high-risk areas. The project included infrastructure works to provide access to basic sanitation, electricity and public lighting services, as well as improving accessibility conditions. Considering the existence of residences in areas susceptible to risk on the slope of the hill, the aim was to reduce the risk of landslides and floods, allowing the consolidation of most families in the intervention area itself.

Learnings and Impact

The main challenge was the prior deficit of federal support and insufficient investment in social programs during the past decade. This was mitigated by restructuring the government ministries through Law No. 14,600, which created the Ministry of Cities and National Secretariat for Peripheries. This gave the programme a shift from a purely thematic approach to a comprehensive territorial strategy, integrating various governmental actions to address multiple needs in the prioritized peripheral territories. The program has created co-benefits such as enhanced community organization, local self-management, and recognition of the potential of peripheral territories. This approach helps address not only infrastructure deficits but also social and economic needs. The initiative shows potential for expansion. Future plans include launching new editions of the Periferia Viva Prize and expanding its reach to more peripheral territories. The program aims to continue transforming peripheral areas by increasing infrastructure investments, supporting various coordinated policies and enhancing disaster resilience to hazards like landslides and floods.

Figure G8.1: Governance Framework of Periferia Viva Programme



DRI Lexicon Words

Coalition for Disaster Resilient Infrastructure (CDRI) has developed a Lexicon on Disaster Resilient Infrastructure (DRI) to foster a shared conceptual understanding of infrastructure-related terms and phrases. It provides a set of globally applicable references to concepts and phrases that can provide a better understanding of the domain, act as a guide to research and understanding, and aid in infrastructure-related decision making of governments, academia and financial institutions, among others.

Lexicon keywords	Definition	Case study
Basic infrastructure	Infrastructure that provides services considered fundamental for human development, growth, safety, and security. https://lexicon.cdri.world/topic/2	G, G1, G3, G8, G8
Blue infrastructure	Bodies of water, watercourses, ponds, lakes and storm drainage that provide ecological and hydrological functions including evaporation, transpiration, drainage, infiltration and temporary storage of runoff and discharge. https://lexicon.cdri.world/topic/232	C5
Cascading hazards	Hazards that are related in a systemic causal relationship and expressed in a sequence of secondary events in natural and human systems that lead to physical, environmental, social, or economic disruption, and where the resulting impact is significantly larger than under a single hazard event. https://lexicon.cdri.world/topic/43	A10, E5, F11
Community infrastructure	Primarily refers to small-scale basic structures, and systems developed at the community level, that are critical for sustenance of lives and livelihoods of the population and are conceived as critical lifelines for survival of the community. These are generally low-cost and small-scale infrastructures, that may develop over time in response to the needs and aspirations of the population, and they may use both community and external resources (e.g., from NGOs, local government). https://lexicon.cdri.world/topic/7	G, G6

Contingent liabilities	Potential liability that may occur in the future depending on the disaster-related outcome of a hazard impact. In disaster risk evaluations, contingent liability refers to future projected damage and loss that must be paid for by the government, individuals, private sector, or others. https://lexicon.cdri.world/topic/109	E
Corrective disaster risk management	Corrective disaster risk management activities address and seek to remove or reduce disaster risks, that are already present, and which need to be managed and reduced now. Examples are the retrofitting of critical infrastructure or the relocation of exposed populations or assets. https://lexicon.cdri.world/topic/162	A, A4
Cost benefit analysis	Quantitative (monetary) assessment of all negative and positive impacts associated with a given action. Cost benefit analysis enables comparison of different interventions, investments or strategies and reveals how a given investment or policy effort pays off for a particular stakeholder. https://lexicon.cdri.world/topic/179	C2, E1, E1, A, A3, A4, A10, C, C2, D2, D4, E, E2, E5, E6, E8, F, F3, F4, F6, F6, F9, F11
Decision support system	An information system that aids an organization in decision-making activities that require judgment, determination, and a sequence of actions. https://lexicon.cdri.world/topic/180	F12, F12, F8
Direct and indirect loss	Direct loss refers to the loss directly associated with original hazard impacts. Indirect loss is a consequence of such direct loss. https://lexicon.cdri.world/topic/113	F11, A4, C2, E8, F1, F7
Disaster preparedness	A condition where different levels and types of social, political and economic organization (and individuals) are able to anticipate and are ready to undertake actions that limit immediate hazard impacts, provide for early recovery, and promote sustainable post disaster recovery, including improved resilience. https://lexicon.cdri.world/topic/155	A, A1, A3, A8, C3, D4, E, E4, F6

Disaster resilience	The ability of a system, community or society exposed to one or more hazards to resist, absorb, accommodate, adapt to, transform, and recover from disasters in a manner that is timely, efficient, and reduces risk, including through the preservation and restoration of essential basic structures and functions. https://lexicon.cdri.world/topic/145	Acknowledgement A, A6, A8, A9, A10, B, B1, C2, C3, D, D4, E, E2, E8, F10, G8
Disaster resilient infrastructure	Infrastructure systems and networks, the components, and assets thereof, and the services they provide, that are able to resist and absorb disaster impacts, maintain adequate levels of service continuity during crises, and swiftly recover in such a manner that future risks are reduced or prevented. https://lexicon.cdri.world/topic/240	Introduction C4, E4, E5
Disaster response	Actions taken once a disaster is imminent or actualized in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. These normally include a strategic perspective on cascading impacts of the event, new/emerging risk conditions as well as needs for rehabilitation, reconstruction, recovery, and resilience building after the disaster event. https://lexicon.cdri.world/topic/228	None
Disaster risk	The potential loss of life, injury, and/or destroyed and damaged assets, which could occur in a system, society or community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity. https://lexicon.cdri.world/topic/71	A9, C5, D1, E2, E3, E4, E5, F4, F6, G1,G4, G6, G8
Disaster risk assessment	Qualitative and quantitative approaches to determine the nature and extent of disaster risk by analyzing existing or potential hazards and evaluating existing or potential conditions of exposure and vulnerability that together could lead to harm to people's lives and livelihoods and to the property, services, livelihoods, and the environment on which they depend. https://lexicon.cdri.world/topic/84	A10,
Disruption and loss of services	A situation whereby access to infrastructure services is interrupted temporarily or lost, following damage or destruction of individual assets or networks or breakdown in the system as a whole. https://lexicon.cdri.world/topic/230	Introduction A3, A10, B3, C2, E2, F4, F7

Flexibility	The ability of an infrastructure system including its governance, material assets and human resources, to serve business-as-usual as well as adjust to shocks/stresses. https://lexicon.cdri.world/topic/182	E5, G6
Green infrastructure	The interconnected set of natural and constructed ecological systems, green spaces and other landscape features that can provide functions and services including air and water purification, temperature management, floodwater management and coastal defense, often with co-benefits for human and ecological well-being. Green infrastructure includes planted and remnant native vegetation, soils, wetlands, parks, and green open spaces, as well as building and street-level design interventions that incorporate vegetation. https://lexicon.cdri.world/topic/17	A9, A10, B, B3, C5, D, D1, D3, D4, F3, F5, G7
Grey infrastructure	Engineered physical structures that underpin energy, transport, communications (including wireless and digital), built form, water and sanitation, and solid-waste management systems and that protect human lives and livelihood. https://lexicon.cdri.world/topic/16	A10, C5, D, F3
Incentive mechanisms for Disaster Resilient Infrastructure	Methods and instruments that promote and/or facilitate the upgrading of existing infrastructure and the building of new resilient infrastructure. https://lexicon.cdri.world/topic/200	C4, E1, F, F9, F10
Indigenous knowledge	Indigenous knowledge is rooted in culture and tradition, and refers to place-based understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. https://lexicon.cdri.world/topic/239	D4
Infrastructure	Individual assets, networks and systems that provide specific services to support the functioning of a community or society. https://lexicon.cdri.world/topic/233	All

Infrastructure interdependencies	Functional linkage(s) within and across different infrastructure sectors or systems (e.g., energy, transportation, telecommunications, water/wastewater, solid waste, and food). https://lexicon.cdri.world/topic/61	E, E5, E6, F6
Infrastructure lifecycle	The series of stages during the lifetime of an infrastructure asset, starting from planning, prioritization and funding to the design, procurement, construction, operation, maintenance and decommissioning. https://lexicon.cdri.world/topic/27	E6
Infrastructure linkages	The notion that infrastructure systems may be highly interconnected and mutually dependent in complex ways. Interlinkages are a significant source of systemic risks, which are increasingly transboundary and transnational. https://lexicon.cdri.world/topic/23	E5
Infrastructure maintenance	Maintenance is a cycle of activities designed and undertaken to preserve the optimal functioning of infrastructure, including in adverse conditions. It is a necessary precondition for the preservation of its operational capability, and to guarantee service continuity. https://lexicon.cdri.world/topic/201	A1, A8, A9, A10, B1, B2, D1, D4, E4, E10, F4, F10, F12, G2, G4
Infrastructure systems	Arrangements of infrastructure components and linkages that provide a service or services. https://lexicon.cdri.world/topic/235	Introduction B, C4, E, E2, E5, E5, E6, E8, F3, F11
Infrastructure vulnerability	Sensitivity or susceptibility of a system to harm, and its lack of capacity to cope and/or adapt to stresses and shocks. https://lexicon.cdri.world/topic/67	E5
Local infrastructure	Facilities at the local level, including water, drainage and sanitation networks, road, river and rail networks, bridges, health, and education facilities, as well as other local facilities services to individuals, households, communities, and businesses in their current locations.	G3, G6

Local knowledge	The knowledge which people in each sub-national setting or community have developed over time and continue to develop with regard to their environment, culture and society. https://lexicon.cdri.world/topic/30	B, D4, E8
Multi-hazard	Specific contexts where hazardous events may occur singly, simultaneously, cascadingly, or cumulatively over time, taking into account the potential interrelated effects. https://lexicon.cdri.world/topic/62	A, E6, E8
Nature-based solutions	Actions based on the protection, conservation, restoration, sustainable use and management of natural or modified terrestrial, freshwater, coastal and marine ecosystems. These actions address social, economic, governance and environmental challenges effectively and adaptively, while simultaneously, ecosystem services, disaster risk reduction, resilience and biodiversity benefits and supporting human well-being. https://lexicon.cdri.world/topic/206	Introduction A6, B2, C5, D1, D2, D3, D4, E8, G8, F8
Prospective disaster risk management	Activities that address and seek to avoid the development of new or increased disaster risks. They focus on addressing disaster risks that may develop in the future if disaster risk reduction policies are not put in place. https://lexicon.cdri.world/topic/164	C, C1, C3, F3, F5, F11, G7
Redundancy	Alternative or back-up means created within an infrastructure system to accommodate disruption, extreme pressures, or surges in demand. It includes diversity, i.e., the presence of multiple ways to achieve a given need or fulfil a particular function. https://lexicon.cdri.world/topic/187	A1, E5
Reliability	Ability of an infrastructure asset or system to perform the desired function based on specified requirements over time without interruption or degradation. https://lexicon.cdri.world/topic/188	A1, A8, E4, F3

Resilience assessment	A qualitative and quantitative approach to determine the extent of resilience by analysing the potential risk and the existing capacity to resist, absorb, accommodate, adapt to, transform, and recover from the negative effects associated with a disaster in a timely and efficient manner. https://lexicon.cdri.world/topic/100	E5
Resilience pathways	Strategies and actions for reducing, managing, and recovering from impacts of disasters. With reference to infrastructure development, resilience pathways refer to perspectives, strategies and actions that help infrastructure systems to withstand and recover from disasters in a timely and efficient manner with minimal impact on essential basic structures and functions. https://lexicon.cdri.world/topic/170	E8
Resilience plan	A resilience plan involves developing goals and coordinating or integrating policies, programmes and actions taken across infrastructure sectors and diverse stakeholder groups, to reduce risks, and to enable communities to adapt and thrive when faced with challenges related to natural and human-caused hazards. https://lexicon.cdri.world/topic/169	A10, B, C, C1, D4, E, F, F8
Retrofitting	Reinforcement or upgrading of existing physical structures to become more resistant and resilient to the damaging effects of hazards. https://lexicon.cdri.world/topic/226	Introduction B, B3, E4, F, F9, G, G6
Risk model	A mathematical representation of a system, whose aim is to quantify the probability, location, and intensity of a future adverse event and its consequences due to exposure and vulnerability conditions. These models typically use historical data, expert knowledge, and theoretical insights in their construction. More recently in the context of climate change, risk models also take into account future climate scenarios. https://lexicon.cdri.world/topic/104	C3, E, E2

Robustness	The inherent strength of an infrastructure asset or a system to withstand shocks and stresses that may be intrinsic or extrinsic in nature, without degradation or loss of functionality. https://lexicon.cdri.world/topic/190	D4, E7
Stress testing	Type of performance efficiency testing conducted to evaluate an asset or system's performance under conditions beyond specified requirements. https://lexicon.cdri.world/topic/105	Introduction E, E5
Systemic resilience	A property of an infrastructure system that manifests when the larger system is organized in such a way that it can provide agreed critical services (power, heat, communications, mobility, water, and waste management) despite the impacts on its constituent systems, networks and assets due to a variety of hazard(s). https://lexicon.cdri.world/topic/241	A8, C1, E1
Systemic risk	In the context of infrastructure, systemic risk is a cumulative risk to a system as an outcome of physical, biological, social, environmental, or technological shocks and stresses. These may be internal or external to the system. Impact on individual components of the system (assets, networks, and subsystems) becomes systemic due to interdependence and interactions between them. https://lexicon.cdri.world/topic/77	C5, E, F3

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