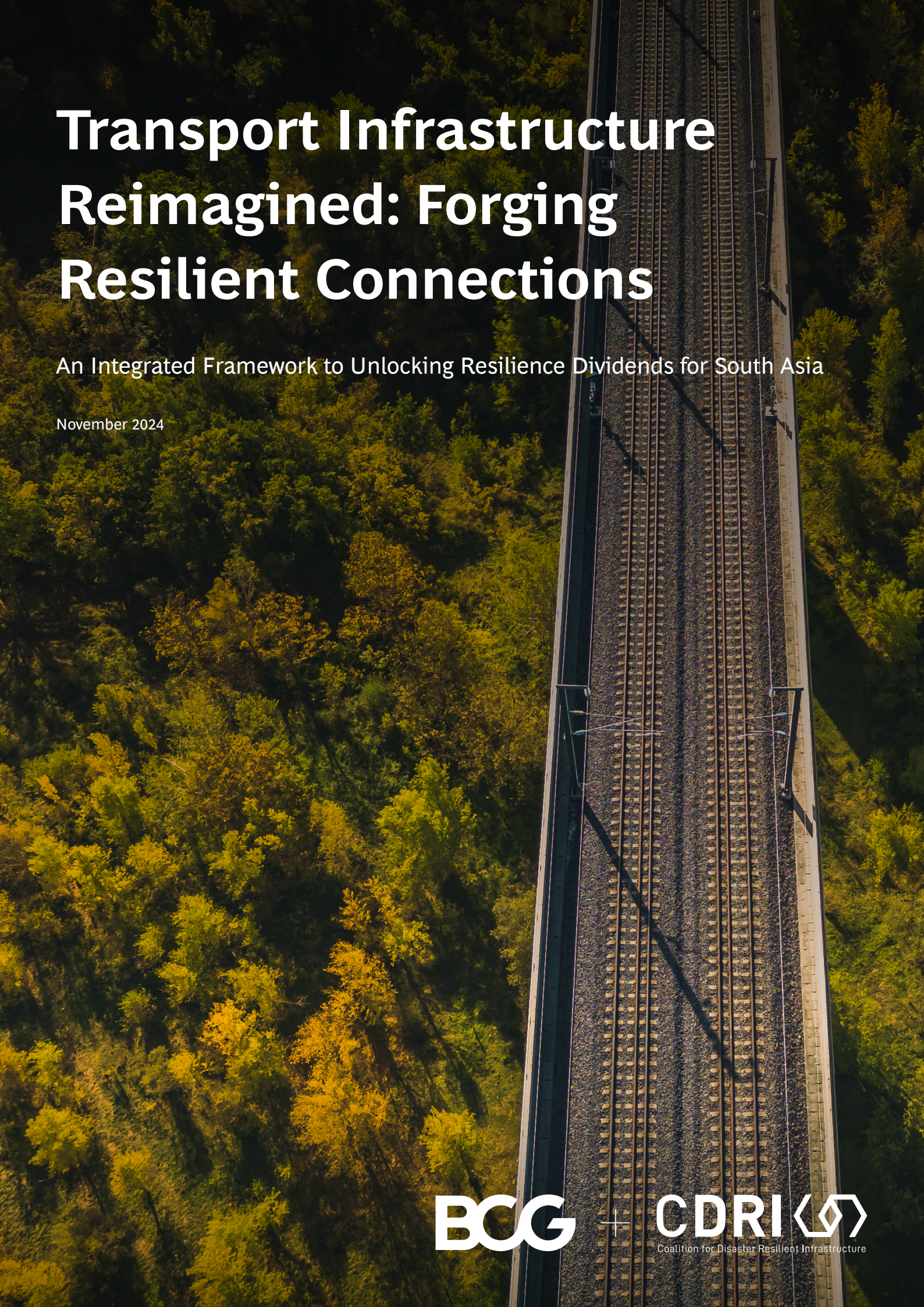

Transport Infrastructure Reimagined: Forging Resilient Connections

An Integrated Framework to Unlocking Resilience Dividends for South Asia

November 2024

BCG + CDRI
Coalition for Disaster Resilient Infrastructure

Boston Consulting Group partners with leaders in business and society to tackle their most important challenges and capture their greatest opportunities. BCG was the pioneer in business strategy when it was founded in 1963. Today, we work closely with clients to embrace a transformational approach aimed at benefiting all stakeholders—empowering organizations to grow, build sustainable competitive advantage, and drive positive societal impact.

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Launched by the Prime Minister of India at the 2019 United Nations Climate Action Summit, Coalition for Disaster Resilient Infrastructure (CDRI) is a global partnership of national governments, UN agencies and programmes, multilateral development banks, the private sector, and academia.

CDRI was accorded the status of an 'International Organization' by the Government of India via a Headquarter Agreement in August 2022. CDRI advances the cause of climate and disaster resilient infrastructure (DRI), thereby ensuring sustainable development.

The Coalition's resilience programmes draw on the operational principles of collaboration, inclusion and focus on the most vulnerable, while considering the emerging priorities of its Members in the backdrop of a rapidly exacerbating context of climate extremes and disaster risk. As a global partnership, CDRI ensures that the investments of its members and partners are aligned and well-coordinated in support of the shared ambition of disaster and climate resilience of new and existing infrastructure.

Foreword

As geo-climatic hazards increase in both frequency and intensity, infrastructure assets valued at billions of dollars are at risk across the world. Almost 14 percent of annual global GDP growth could be wiped out each year due to disaster-related infrastructure damages. A large part of this risk is concentrated in the developed economies where substantial infrastructure investment has already been made. Developing economies on the contrary have a considerable amount of infrastructure deficit. This gap in infrastructure is also an extraordinary opportunity to invest in resilient infrastructure, such that the future risk of damages is minimized, and the losses related to disrupted services are reduced.

In South Asia region – having some of the world's fastest growing economies – two actions will be needed. The first is to invest in safeguarding existing infrastructure assets from risks posed by geo-climatic hazards – whereby strengthening resilience of infrastructure valued at US$ 2 trillion (in 2022). The second is to make all future infrastructure investments disaster resilient. According to a World Bank (2019) report, investing US$ 1 in resilience can give back an average of US$ 4 in avoided future losses.

A substantial amount of infrastructure investment across South Asia is expected in the transport sector. CDRI's analysis finds that the transportation sector – an economic backbone – is at considerable risk from disasters related to flooding, landslides and other geo-physical hazards. Investing in transport sector resilience can help safeguard against these risks, whilst also yielding significant 'resilience dividends,' including broader benefits such as economic stability, environmental sustainability, and enhanced public services that will outweigh the initial investment in resilience.

This report is a step in that direction. A framework is presented that integrates components like policy and regulation, data and technology, financial considerations, governance and capacity development as an approach to embed resilience in South Asia's transport sector. Concrete steps are also outlined that stakeholders can take to embed disaster resilience throughout the project life cycle. Attaining infrastructure resilience necessitates enhanced cooperation among all infrastructure stakeholders including national and subnational governments, private and public infrastructure entities, financial institutions, think-tanks and academia. Each stakeholder has a crucial role to play in placing resilience at the core of every infrastructure decision for a systemic transformation.

We hope that this report – a collaborative effort by Boston Consulting Group (BCG), and the Coalition for Disaster Resilient Infrastructure (CDRI) – will catalyse a region-wide conversation on the need for climate and disaster resilient transport infrastructure. We also expect that it will be useful for all stakeholders across the south Asia region and will foster collaborative actions towards enhanced infrastructure resilience.

Amit Prothi
Director General
Coalition for Disaster Resilient Infrastructure

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Executive Summary

Resilience should be the cornerstone of transport infrastructure planning, to prepare us for inevitable climate impacts and avert catastrophic economic, physical, and environmental losses

Extreme weather events triggered by geo-climatic hazards present a significant challenge to infrastructure worldwide. The transport sector, accounting for over 50 percent share of exposed infrastructure globally at approximately US$ 90 trillion (as of 2022)[1], faces acute vulnerability to climate disruptions. In South Asia[2], transport assets worth approximately US$ 575 billion are exposed to climate hazards as of 2022[3], posing risks to a sector that contributes four to eight percent of the region's GDP[4]. These risks extend beyond direct physical damage, as disruptions in transport networks can trigger cascading failures across interconnected economic systems, impacting supply chains, manufacturing schedules, and overall economic output.

In the face of a changing climate, resilient transport systems emerge as the foundation for continued economic stability and growth. By proactively addressing vulnerabilities in both existing and planned transport infrastructure, the region could avert over US$ 1 billion in direct damages annually[5]. Investing in infrastructure resilience offers substantial returns, with the World Bank estimating that resilience investment in developing countries could yield four times the benefit[6]. However, while resilience financing has progressed, it still represents only 20-30 percent of the US$ 215-387 billion needed annually by 2030 in developing countries[7]. Moreover, businesses integrating Adaptation and Resilience (A&R) plans can abate losses of up to 15 percent of Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA) by 2040[8]. Beyond economic gains, resilient infrastructure provides critical environmental and social impacts. To unlock the full scale of benefits that resilient infrastructure can offer, swift, concerted action from governments, businesses, and financial institutions to safeguard our transport networks and economic future is the primary agent of change.

Transport infrastructure assets span diverse categories, each requiring tailored interventions to ensure resilience. Every transport asset type—roads, railways, ports, and airports faces unique vulnerabilities to various hazards and calls for designing and implementing bespoke measures. There is need to embed resilience for all asset types through a mix of green and grey interventions at every stage of a project's lifecycle—from strategy and planning through to end-of-life. This methodology would ensure long-term adaptability and holistic risk management across intertwined transport networks.

A cohesive framework will guide coherent resilience initiatives in transport. Early evidence of effective resilience practices in transport exists; however, the pressing need is for a synergistic, interlinked strategy, calling for a renewed approach in how resilience is considered today. To solidify and accelerate progress in this area and activate the entire ecosystem in South Asia, the structure encompasses:

- **Application of an infrastructure project:** Lifecycle-oriented lens, embedding resilience from strategy to end-of-life
- **Deployment of strategic enablers:** Robust policy frameworks & regulatory regimes, scientific data-driven execution strategies, and innovative financing models
- **Prioritization of critical accelerators:** Capacity development & governance to drive resilience initiatives

[1] Global Infrastructure Resilience Index (2023); [2] For the purpose of this report, South Asia is defined to include the following eight countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka; [3] Ibid; [4] BCG Analysis based on sectoral GDP contributions of South Asian countries (2023); [5] Global Infrastructure Resilience Index (2023); [6] World Bank (2019); [7] World Economic Forum (2024); [8] Based on BCG project experience

The report proposes an integrated framework that places resilience at the core of every decision across the project lifecycle, with a focus on strategic enablers and critical accelerators. This demands efforts by diverse stakeholders—from governments and infrastructure entities to financial institutions and think tanks—to create a unified front in building resilient transport systems.

Responding to six calls to action could drive resilience across South Asia's transport infrastructure

1. Develop national & subnational A&R plans to align policy measures across sectors including transport infrastructure, with measurable targets
2. Mainstream Climate Risk Assessments in prefeasibility stage of greenfield and brownfield infrastructure projects to integrate climate risk evaluations into infrastructure planning
3. Establish comprehensive transport infrastructure codes and standards to ensure uniform application of climate-resilient measures across projects
4. Incorporate resilience in procurement for infrastructure projects
5. Embed resilience in skill development to create a workforce equipped to design and manage climate-resilient infrastructure through targeted modules
6. Enhance availability & access to finance to scale up the implementation of resilient projects in transport infrastructure through innovation in financing sources and instruments

Stakeholder orientation & coordination is a crucial imperative to implement the resilience framework; national and subnational governments, private and public infrastructure entities, financial institutions, thinktanks and academia play pivotal roles in varying capacities. Given mainstreaming of resilience is in relatively nascent stages in South Asia, the public sector has a leadership role to play in this transformation, with support from collaborators. This will lead to fostering ownership, leveraging diverse expertise, and in turn, accelerating implementation.

South Asia faces a dire need to protect its critical transport infrastructure from increasing climate risks. Acting now offers substantial economic, societal, and environmental benefits. By taking decisive steps, the region can lead the way in climate-resilient infrastructure, fostering innovation and sustainable growth.

Infrastructure Resilience: The Opportunity

Vision and trajectory for national economic growth can be sustained only by prompt integration of resilience in existing and planned infrastructure, as climate impacts get increasingly severe with time

Climate change is accelerating rapidly, unleashing impacts of considerable scale and frequency. At the same time, global climate action is falling short of the Paris Agreement targets. The world is veering off course from limiting temperature rise to 1.5°C or even 2°C. The Intergovernmental Panel on Climate Change (IPCC) projections paint a grim picture: under business-as-usual scenarios, the world is heading for a 2.2°C to 3.5°C increase[1]. This trajectory leads to intensified physical risks & severe economic impacts. In 2023, 400 disasters reported globally affected 93 million people and inflicted economic damages totaling more than US$ 202 billion[2].

[1] IPCC (2023); [2] Centre for Research on the Epidemiology of Disasters (2024)

This trend is reflected in rising economic losses from natural disasters: between 2005 to 2009, global economic damages averaged US$ 228 billion annually, but by 2019-2023, this figure had more than doubled to US$ 378 billion, driven by the increasing frequency and severity of climate impacts[3]. While resilience financing has seen progress, reaching a record US$ 63 billion in 2021-2022, this still represents only 20-30 percent of the estimated US$ 215-387 billion needed annually by 2030 in developing countries[4]. By 2050, the costs of adaptation are expected to be four to five times higher than current projections[5].

Infrastructure assets deliver essential services such as water, sanitation, energy, and transportation to businesses, and communities. Hazards now exacerbated by climate change threaten critical infrastructure causing asset loss and service disruptions. The scale of this challenge is immense; infrastructure assets across all sectors worth approximately US$ 180 trillion (as of 2022) are exposed to climate change-induced risks, with South Asia[6] alone facing exposure of nearly US$ 2 trillion in 2022[7].

However, addressal of this crisis also unveils a unique opportunity. Given most of the global infrastructure to be required by 2050 is yet to be built[8], we stand at a pivotal moment to shape the future of climate-resilient infrastructure and fuel early movers. (See Exhibit 1)

> **Economy wide returns: World Bank estimates that a US$ 1 trillion investment in infrastructure resilience in developing countries could yield US$ 4.2 trillion in benefits.**
> *—World Bank (2019)*

A massive potential awaits all infrastructure stakeholders in converting these challenges into opportunities for innovation and long-term value creation. Addressing this head-on now will not only help stakeholders secure these assets but also shape the path forward for climate and disaster resilient infrastructure.

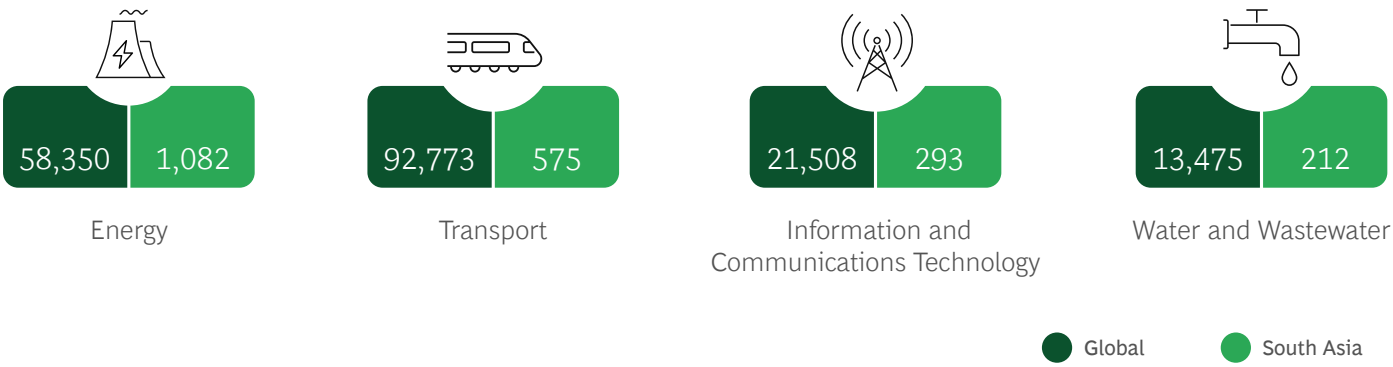
> **Building resilience into businesses: By integrating A&R strategies, businesses can abate losses to the tune of 15 percent of EBITDA[9] by 2040 and avert risk to the tune of 23 percent to global GDP by 2100[10].**

Natural systems like mangrove forests protecting coastal transport infrastructure offer substantial environmental and social returns. They provide protection valued at over US$ 80 billion annually in avoided losses from coastal flooding, safeguarding 18 million people. These ecosystems contribute up to US$ 50 billion yearly in non-market benefits associated with fisheries, forestry, and recreation, with investments yielding returns up to 10 times the initial costs, highlighting their efficiency in enhancing infrastructure resilience[11]. (See Exhibit 2)

Transport infrastructure, a vast network that stretches across both urban and rural areas, stands as the most geographically extensive of all infrastructure types. This ubiquitous presence across diverse landscapes, from coastal highways to mountain railways, .renders it uniquely vulnerable to the full spectrum of geo-climatic hazards. It accounts for the highest exposure by a big margin globally and ranks second highest in South Asia after the energy sector[12]. Transport evidently emanates as one of the key sectors most threatened by a range of hazards causing extreme events globally. Disruptions in one part of the transport network can trigger cascading failures across the entire economic system. A delay at a port does not just affect maritime trade; it reverberates through road and rail

Exhibit 1: Value of Assets Exposed across All Infrastructure Sectors

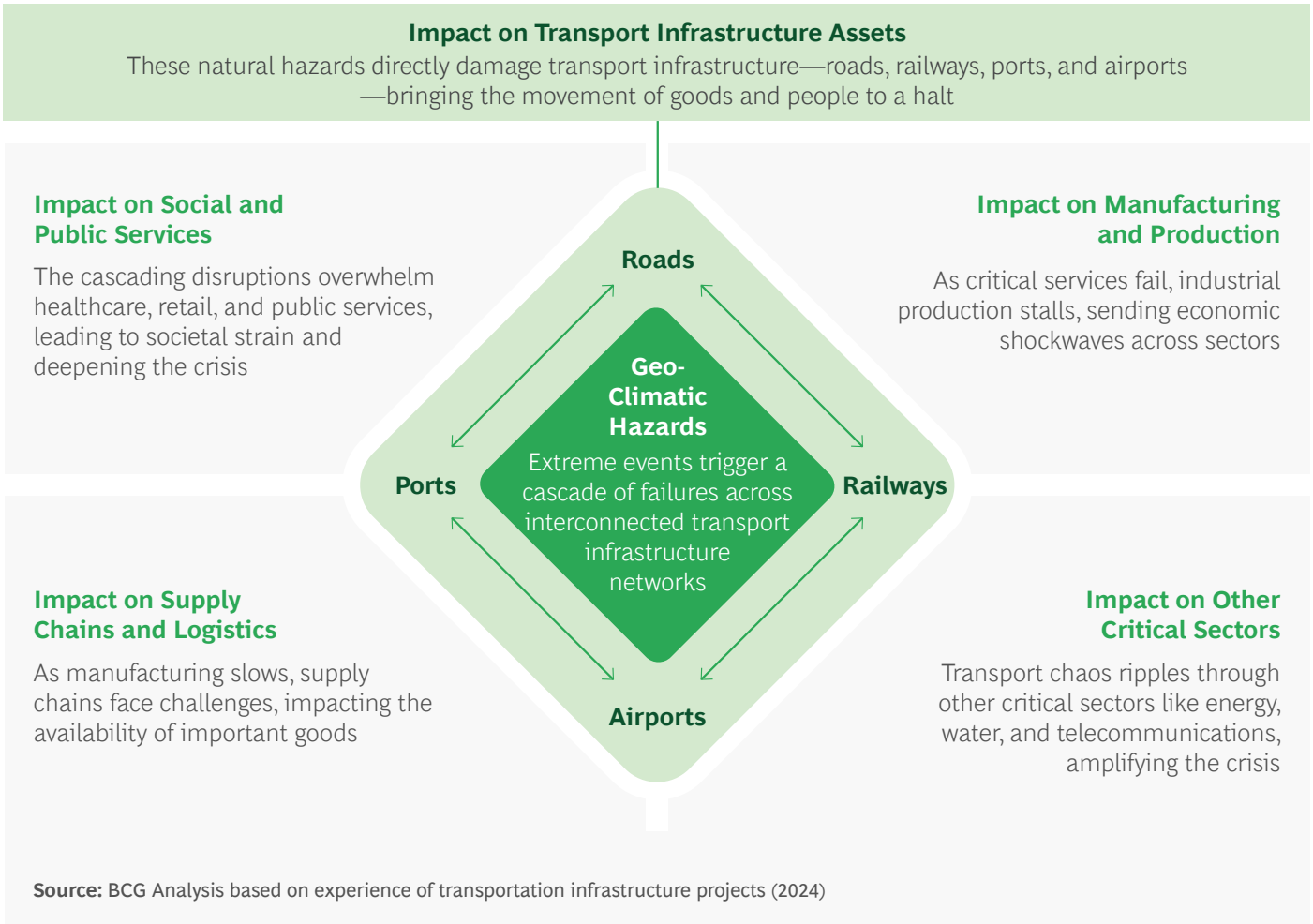
All values in US$ billion



Source: Global Infrastructure Resilience Index (2023)

[3] AON (2024); [4] World Economic Forum (2024); [5] UNEP (2014); [6] For the purpose of this report, South Asia is defined to include the following eight countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka; [7] CDRI (2023); [8] Ibid; [9] Earnings Before Interest, Taxes, Depreciation, and Amortization; [10] Adaptation & Resilience through Land Transport Infrastructure Systems (2023); [11] Global Commission on Adaptation (2019); [12] Global Infrastructure Resilience Index (2023)

Exhibit 2: Interconnectivity with Other Infrastructure Drives Complexity



Source: BCG Analysis based on experience of transportation infrastructure projects (2024)

logistics, impacting supply chains, manufacturing schedules, and ultimately, economic output. For example, in 2019 Typhoon Lekima led to a five-day shutdown at the port of Dalian in Northeast China, inflicted economic damage of US$ 65 million[13].

This intricate web of dependencies extends beyond transport, intertwining with energy, telecommunications, and water infrastructure, amplifying the risk for systemic collapse in the face of climate-induced shocks. Thus, building resilience into transport infrastructure—the ability to adapt, withstand, and recover from climate impacts—is paramount for economic and societal stability.

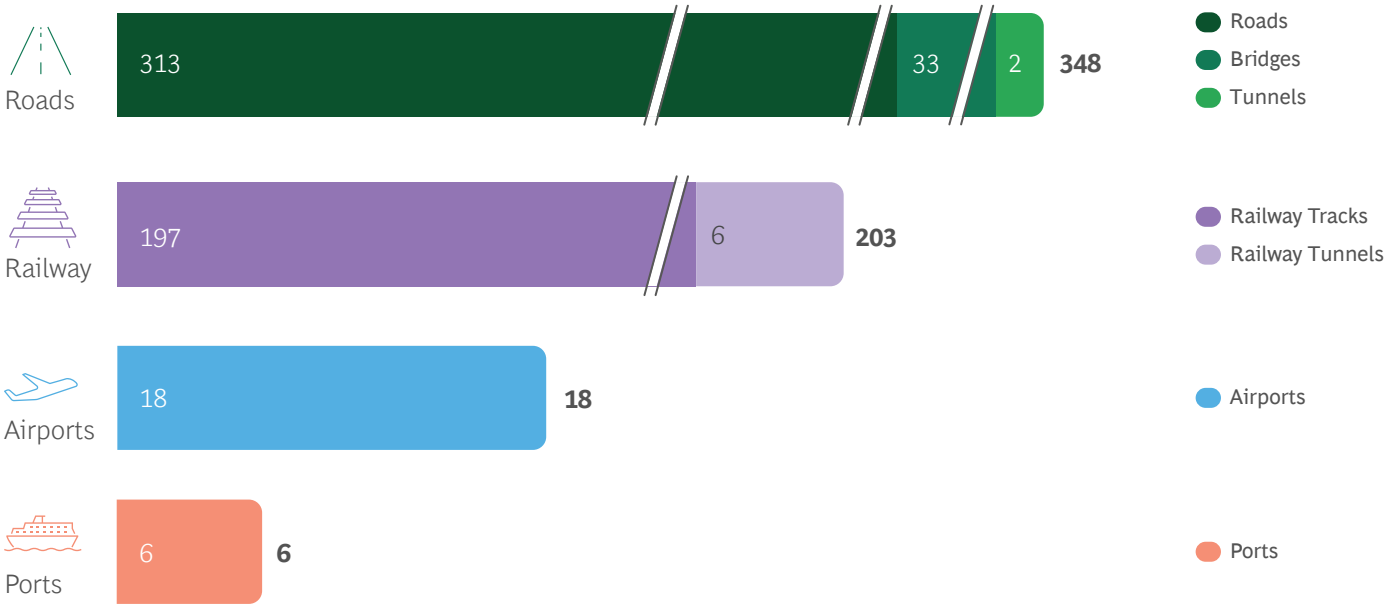
The transport sector is a critical lifeline for South Asia, contributing a significant four to eight percent to the total GDP of the region (as of 2023)[14], underpinning several direct and indirect jobs and acting as the conduit for other critical sectors such as manufacturing, agriculture, and services. As of 2022, transport assets worth US$ 575 billion are exposed to geo climatic hazards in South Asia[15]. (See Exhibit 3)

Making infrastructure resilient is vital for South Asia, a region home to a quarter of the world's population and contributing to over 4 percent of the global GDP[16]. With the highest population density globally—about 400 people per square kilometre (as of 2021) compared to the world average of 60 people per square kilometre (as of 2021)[17]—climate impacts here have far-reaching consequences. The region's vulnerability is further exacerbated by its underdeveloped transport infrastructure, much of which lacks resilience as per global standards. This infrastructural deficit, coupled with the region's high climate risk—five South Asian countries rank in the top 20 of the Global Climate Risk Index—make South Asian transport infrastructure extremely susceptible[18].

[13] Environmental Defense Fund and RTI International (2022); [14] BCG Analysis based on sectoral GDP contributions of South Asian countries (2023); [15] Global Infrastructure Resilience Index (2023); [16] World Bank (2023); [17] Ibid; [18] Germanwatch (2021)

Exhibit 3: Asset Level Exposure (as of 2022) in the Transport Sector in South Asia

All values in US$ billion



Source: Global Infrastructure Resilience Index (2023)

By proactively addressing vulnerabilities in both existing and planned infrastructure for the transport sector, the region could mitigate more than US$ 7 billion[19] in direct losses till 2030. Such foresight would not only secure economic stability but also lay the groundwork for more effective disaster management measures. As South Asia stands at this pivotal moment, the decisions taken today in infrastructure development will set the foundation for the region's resilience and economic trajectory for decades to come.

[19] BCG Analysis based on Annual Average Loss provided by Global Infrastructure Resilience Index (2023)

Embedding Resilience in Transport Infrastructure

Safeguarding South Asia's transport infrastructure requires embedding resilience at every stage of the lifecycle, ensuring long-term adaptability and risk mitigation across all transport asset types

Building a pathway to resilience for transport infrastructure across South Asia is complex, with climate change impacts varying significantly across asset types and locations. Roads, railways, ports, and airports each confront unique vulnerabilities to floods, landslides, tropical cyclones, droughts and earthquakes. The severity of these geo-climatic hazards fluctuates by region, creating a mosaic of risk exposures across the subcontinent. To safeguard South Asia's economic vitality and social fabric, it is crucial to dissect the vulnerabilities of each asset class viz. roads, railways, airports and ports.

Roads

South Asia's expansive road network, spanning more than 7 million kilometres[1], confronts critical vulnerabilities with US$ 348 billion[2] in assets exposed to climate risks as of 2022.

- Increased temperature variability causes greater stress on expansion joints in bridges, leading to premature structural failure and misalignment of components
- Increased and erratic rainfall patterns lead to water infiltration into road subgrade infrastructure, weakening subgrade materials and thus destabilizing pavements
- Extreme heat accelerates asphalt softening and cracking of concrete, causing surface deformations and breakdowns

Railways

The region's railway network, extending over 130 thousand kilometres[3], faces significant climate risks, with an estimated US$ 203 billion[4] in assets exposed to extreme weather events as of 2022.

- Extreme heat induces deformation and buckling of railway tracks, leading to misalignment and compromising safe operations
- Increased rainfall intensity and flooding cause track washouts by eroding the track bed and ballast, resulting in severe service disruptions
- High winds and storms damage overhead catenary systems and signal infrastructure, affecting power supply and train operations

Airports

With more than 270 airports[5] serving 260 million[6] passengers annually, South Asia's aviation sector is increasingly susceptible to climate impacts. As of 2022, these airports held US$ 18 billion[7] in infrastructure assets exposed to climate risks.

- Increased frequency and intensity of storm surges cause inundation of runways and aprons, leading to operational shutdowns and flight disruptions
- More frequent and severe storms disrupt power supply systems, affecting critical components of airports like lighting, navigation, and communication systems
- Flooding, storms, and heat waves cause power outages, equipment failures, and unsafe working conditions, weakening emergency response capabilities and disaster recovery efforts

Ports

Handling 34 million[8] Twenty foot Equivalent Units (TEUs) of container traffic annually, South Asia's port infrastructure is also at risk, with US$ 6 billion[9] worth of assets vulnerable to climate related hazards as of 2022.

- Increased storm surges and flooding cause inundation of docks and berths leading to operational shutdowns, delayed cargo handling and disrupting supply-chain.
- Extreme weather events increase sediment buildup, requiring more frequent dredging to maintain navigable waterways and port efficiency
- High winds and cyclones damage cranes, terminal infrastructure, and storage facilities, reducing cargo handling capacity and operational efficiency

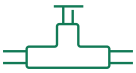
[1] BCG Analysis based on road network data of South Asian countries (2023); [2] Global Infrastructure Resilience Index (2023); [3] BCG Analysis based on rail network data of South Asian countries (2023); [4] Global Infrastructure Resilience Index (2023); [5] BCG Analysis based on airports data of South Asian countries (2023); [6] Ibid; [7] Global Infrastructure Resilience Index (2023); [8] BCG Analysis based on ports data of South Asian countries (2023); [9] Global Infrastructure Resilience Index (2023)

Geo-climatic hazards uniquely impact each transport asset type, calling for tailored interventions to build resilience into roads, railways, ports and airports

While each transport asset is impacted differently by geo-climatic hazards, common themes emerge, which if tackled appropriately can present a roadmap for other asset types to adopt based on local context. Analysis of these asset-specific vulnerabilities reveals three distinct risk categories that cut across South Asia's transport infrastructure, viz. (a) structural integrity, (b) drainage, and (c) operations & maintenance, necessitating holistic solutions that blend robust planning & engineering with adaptive management.

Structural Integrity

The structural integrity of transport infrastructure is increasingly compromised by the rising frequency and intensity of climate-related hazards. Heavy rainfall significantly weakens infrastructure when materials and designs are not resilient enough to withstand prolonged exposure to water. During rainfall, water seeps into cracks and weak points in roads, bridges and railway tracks, causing erosion, swelling of subgrade and undermining foundational stability. Inadequate protective coatings and outdated construction materials allow water to penetrate and weaken load-bearing components, leading to cracking, corrosion, and degradation over time. Similarly, extreme heat causes materials like asphalt and concrete to expand, leading to cracks, warping, and the weakening of structural elements. Many existing assets, often built decades ago, were not designed for these new extremes, leaving them vulnerable to failure.



Drainage

As geo-climatic hazards like urban floods and high intensity rainfall become more frequent due to climate change, drainage systems that were once adequate now fall short of meeting today's challenges heightened by climate change. Many systems, such as culverts, are unable to discharge the current water volumes, leading to waterlogging, pavement erosion, and damage to modal assets, disrupting networks and economies. The problem is particularly acute in urban areas, where rapid development often outpaces infrastructure upgrades. Aging and inadequately maintained drainage infrastructure, often clogged by silt and debris, further exacerbates these issues. Designed as an afterthought in many transport systems, drainage is often isolated from broader infrastructure planning, resulting in cascading failures like road erosion and railway destabilization, underscoring its critical role in overall resilience.

Operations & Maintenance (O&M)

The resilience of transport infrastructure is also heavily dependent on effective operations and maintenance practices, which are often insufficient to meet the growing demands posed by climate change. Absence of regular monitoring and routine maintenance leads to the deterioration of roads, bridges, and railways, making them more susceptible to damage from extreme weather events. Inadequate inspections, outdated maintenance schedules, and limited resources further contribute to the problem, allowing minor issues—like cracks, material fatigue, and drainage blockages—to escalate into major structural failures. Climate-induced wear and tear, such as heat stress and water damage require more frequent and specialized maintenance approaches, yet many transport systems still rely on reactive, rather than proactive, maintenance plans. Foresight and strategic planning can significantly extend the lifespan of infrastructure assets, streamline repairs, and reduce costs, facilitating resilient transport networks.

Efforts to tackle these thematic vulnerabilities are deeply interconnected and must be addressed in tandem to build a truly resilient transport infrastructure prepared to handle climate impacts of the future. Structural weaknesses can exacerbate drainage issues, and vice versa, just as inappropriate maintenance practices can lead to structural degradation and compromised drainage. Solutions that integrate these elements across transport projects, tailored to specific national and subnational contexts, are crucial. Interlinked efforts, driven by coordinated planning are essential to ensuring that initiatives in one area support resilience in the others.

Countries across the globe have adopted measures to weave resilience interventions into transport infrastructure projects which address the challenges outlined above. These real-world examples showcase a range of effective measures, applicable across greenfield and brownfield projects that can be tailored based on respective national circumstances. (See Exhibit 4)

Exhibit 4: Global Good Practices for Integrating Resilience in Transport Infrastructure across Common Themes

Structural Integrity

Upgrading **expansion joints** on bridges and rail tracks to **accommodate larger thermal expansion and contraction,** ensuring resilience to greater temperature fluctuations.

Applying **heat-reflective coatings and cool pavements,** along with appropriate bitumen grades enhanced with performance modifiers on roads and runways to reduce thermal stress and improve durability.

Utilizing **corrosion-resistant and flexible materials** to prevent structural degradation.

Incorporating **paving fabrics, geotextiles, or Stress Absorbing Membrane Interlayer (SAMI)** to reduce cracking and water intrusion.

Enhancing **seismic resilience** with base isolation, seismic dampers, and reinforced retaining structures.

Implementing slope protection works by constructing **gabion walls, retaining walls, and protecting abutments** using locally abundant materials.

Drainage

Retrofitting **bridge openings, culverts, tunnels, runways, docks, and piers** to handle heavier rainfall and flooding, based on detailed asset-level assessment.

Installing **geo-composite drainage systems** beneath pavements and tunnels while integrating **natural drains with engineered infrastructure** to manage subsurface and surface water.

Implementing **multi-layered flood defenses** with elevated structures, physical barriers, and dewatering systems, **incorporating geosynthetics** in flood-prone areas.

Operations & Maintenance (O&M)

Increasing redundancy, **elevating electrical installations,** and implementing **off-grid energy solutions.**

Strengthening **emergency response capabilities** and **restoration mechanisms** with designated emergency routes for rapid disaster recovery.

Ensuring **regular maintenance and management of support systems** and other structural components of transport assets.

CASE STUDY 1

Strengthening Climate Resilience in Road Infrastructure: US DoT's Adaptation Strategies[1]

Material Hazards & Threats

Climate change is intensifying pressures on U.S. transportation systems through rising temperatures, sea levels, and altered precipitation patterns, leading to more frequent extreme weather events that threaten critical road infrastructure and mobility.

Key Interventions

Adjusted Pavement Binder and Mix Design Specifications

State agencies modified asphalt binder aznd mix design specifications to better align with expected future environmental conditions, incorporating stiffer asphalt grades suitable for higher temperatures to enhance pavement resilience against climate-induced damage

Enhanced Structural Design of Pavements

Adapted concrete pavement structural designs to mitigate risks from rising groundwater levels and increased precipitation, implementing robust designs to minimize moisture damage and shrinkage, and utilizing stabilized subbases and base materials in vulnerable areas

Critical Route Identification and Elevation

Identified and elevated crucial transportation segments, such as segments on Gandy Boulevard, to ensure safer and more reliable evacuation routes during emergencies, particularly hurricanes, in regions like Pinellas County

Improved Transportation Asset Management

Integrated risk-based asset management plans into decision-making processes, enabling state Departments of Transport (DOTs) to optimize investments in infrastructure improvements and evaluate long-term resilience interventions for vulnerable roads, highways, and bridges

Successes Unlocked

- **Upgraded Pavement for Coastal Flooding** by implementing a US$ 1 million project in Rhode Island, where a 2,000 foot section of North Road was coated with permeable pavement to mitigate coastal flooding impacts[2]
- **Improved Infrastructure Resilience** through the PROTECT program, established under the Bipartisan Infrastructure Law, which allocated US$ 8.7 billion for enhancing the resilience of highways, rail, and ports, reducing recovery times after extreme weather events[3]
- **Extended Road Lifespan** by modifying pavement designs to withstand higher temperatures and increased precipitation, reducing repair costs and prolonging road usability
- **Enhanced Governance & Capacity Building** by institutionalizing evidence-based learning through FHWA's Climate Challenge, providing US$ 7.1 million in funding and technical assistance across 27 state and local agencies to integrate climate resilience strategies into transportation planning[4]

[1] FHWA (2017) & FHWA (2018); [2] Center for Environmental Excellence by AASHTO (2022); [3] U.S. DOT (2023); [4] FHWA (2024)

To ensure long-term resilience in infrastructure, nature-based solutions emerge as powerful tools that could be integrated into the very fabric of policymaking. These ecological solutions offer a broader strategy to provide comprehensive protection against climate hazards. By creating a multi-layered defense system, such interventions not only safeguard individual assets but also fortify the entire transport ecosystem against climate-induced threats, whose intensity and scale are set to exponentially rise. Global examples demonstrate effective measures that can be tailored to national contexts, such as:

- Conserving and replanting mangroves and rehabilitate coral reefs in select areas as natural defenses against storm surges and coastal flooding
- Implementing retention ponds with natural vegetation and restore salt marshes or peatlands to enhance natural flood absorption
- Establishing land-use buffers and manage vegetation around transport infrastructure to mitigate natural hazard impacts

CASE STUDY 2

Enhancing Flood Resilience in Transport Infrastructure: China's Sponge City Initiatives[1]

Material Hazards & Threats

Rapid urbanization and climate change have rendered Chinese cities increasingly susceptible to severe urban flooding, threatening critical transport infrastructure and urban livability.

Key Interventions

Natural Flood Defense Systems

Adopted a comprehensive strategy combining nature-based solutions with traditional infrastructure to enhance flood resilience

Flood Water Absorption

Redesigned urban roads with permeable pavements, bioswales, and rain gardens to improve water absorption and reduce surface runoff

Wetlands & Retention Ponds

Created multifunctional greenspaces including wetlands, water retention parks, and green roofs along transport corridors and at transit hubs, managing stormwater while enhancing urban greening and reducing heat islands

Water Management

Incorporated advanced stormwater management systems into urban transit projects, such as the Bus Rapid Transit (BRT) corridors, effectively managing excess rainwater

Successes Unlocked

- **Over 5,000 flood resilience projects** across 30 pilot cities. Created 56,000 km of greenways and 72,400 km² of multifunctional green spaces. Significantly bolstered urban transport resilience while improving city livability and environmental quality
- **Enhanced governance & capacity building** by institutionalizing evidence-based learning, aligning policies across agencies, and reforming institutions to integrate sponge city features, ensuring coordinated resilience and disaster risk management across all levels of governance

[1] ADB (2022)

These asset-specific interventions represent only part of the solution. The complexity and interconnectedness of transport systems, coupled with the unpredictable nature of climate risks, necessitate a more comprehensive strategy. These include managing interdependent vulnerabilities across different transport assets, ensuring long-term adaptability to evolving climate risks, improving cost-effectiveness, and enabling holistic risk management that considers a broader range of current and future risks. This systemic outlook does not negate the need for asset-specific interventions. Rather, the implementation of these interventions requires a fundamental shift in our approach to infrastructure development, one that embeds resilience as a core principle not in parts but throughout the entire project lifecycle.

SPOTLIGHT #1

Philippines' National Adaptation Plan (NAP)—A Comprehensive Approach to Embed Disaster Resilience across Key Sectors

The Philippines, consistently ranked as the most disaster-prone country globally, faces unparalleled challenges due to climate-induced disasters. Its transport infrastructure with the nation's geographic positioning, combined with poor infrastructure quality, renders it particularly susceptible to geo-climatic hazards.

This crisis, however, has galvanized a robust national response. At the core of the Philippines' NAP is a data-driven approach to understanding and addressing climate risks. The plan utilizes advanced climate analytics to inform A&R strategies across eight key sectors.

Transport: One of the eight key sector for strategic infrastructure interventions

Enhanced Infrastructure Standards
Revisions to design code to ensure that new transport projects can withstand extreme weather events

Resilient Transport Networks
Prioritize expansion of alternative systems to offer resilient mobility options during disasters

Innovative Technologies
Encourage intelligent transportation & electric vehicles to diversify infra., reducing dependency on traditional systems

These interventions are underpinned by strong governance and innovative financing mechanisms, ensuring a holistic approach to climate adaptation across the transport sector.

Governance and Financing Innovation
Establishing a purpose-fit governance structure and utilizing innovative financing such as the People's Survival Fund and Climate Change Expenditure Tagging align financial resources with resilience goals, ensuring sustained action

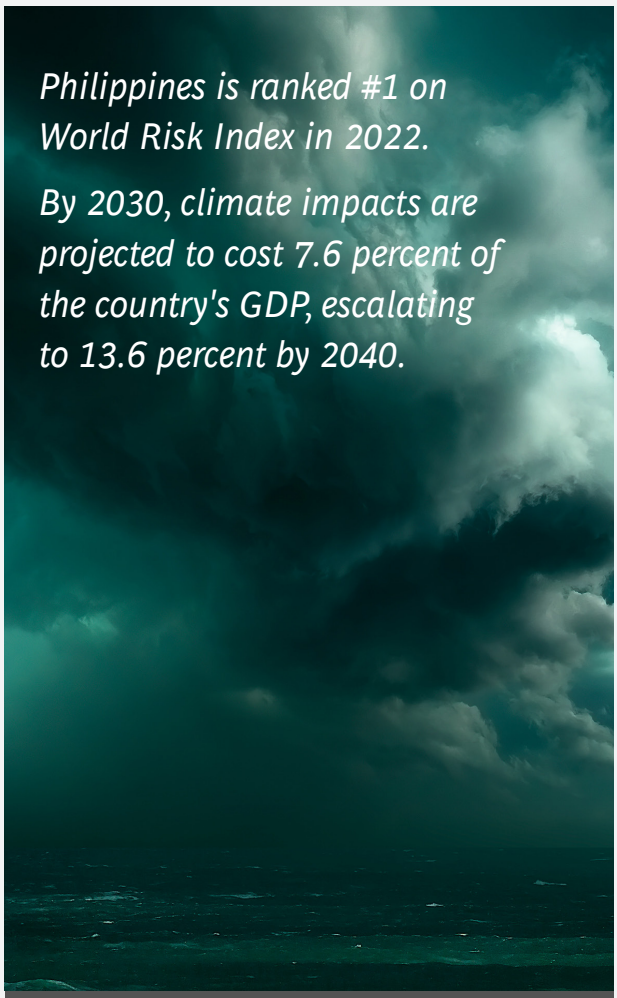
Aims to mitigate climate-related risks, with potential cost of inaction of approximately US$ 25 billion

Social
Relocation costs of US$ 180 million in inundation-prone areas to be avoided

Economic
US$ 9.4 billion to be saved by avoiding productivity loss

Infrastructure
Five percent of the country's transport infrastructure to be preserved

Hazard Mitigation
Improved preparedness for increased geo climatic hazards



Impact and Potential

As climate impacts intensify globally, the Philippines' comprehensive and strategic approach to national adaptation planning serves as a beacon for other nations. It demonstrates that a well-structured, data-driven, and inclusive NAP can chart a path towards resilience and sustainable development.

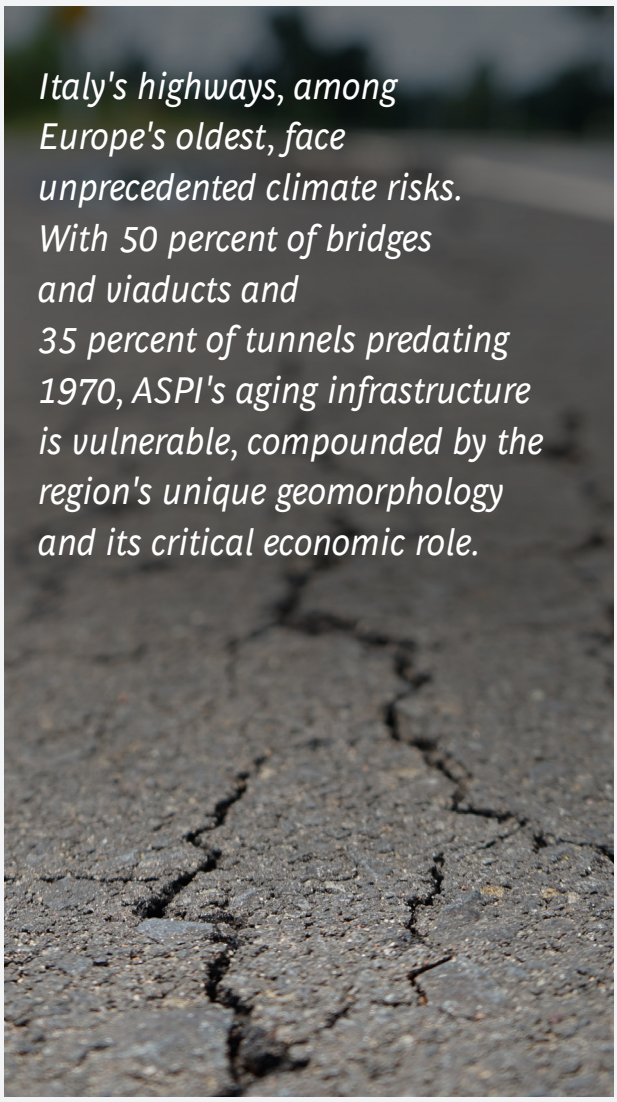
The Philippines' NAP not only addresses immediate climate challenges but also provides a framework for long-term adaptive capacity building, offering valuable insights for global adaptation efforts.

Source: Based on BCG project experience—Philippines National Adaptation Plan (2023)

SPOTLIGHT #2

Autostrade per l'Italia (ASPI) Comprehensive Climate A&R Strategy to Safeguard Italy's Critical Transport Infrastructure

ASPI, responsible for some of Europe's oldest and most complex highway networks, faces acute challenges in the wake of escalating climate risks. In response, ASPI developed a comprehensive climate adaptation strategy encompassing the entire infrastructure lifecycle.



ASPI's climate adaptation strategy employs a resilience curve approach

1. **Readiness:** Use digital inventories and climate risk assessments for infrastructure modernization and operational resilience
2. **Response and Recovery:** Activate crisis protocols during events, assess infrastructure, and ensure timely restoration post-event
3. **Continuous Monitoring:** Deploy sensors and forecasting technologies for real-time environmental tracking and proactive management
4. **Strategic Engagement:** Collaborate with stakeholders at all levels to integrate new regulations, data sharing, and early warning systems

This approach integrates climate resilience along the entire lifecycle, from strategy to end-of-life by focusing on modernization through innovative digital technologies, strengthening infrastructure integration within the hydrogeological context, and ensuring ongoing maintenance with proactive, climate-adaptive measures, all while engaging stakeholders at national and sub national levels, including regulators, academic institutions, and local authorities.

Urgency of these efforts was underscored by the catastrophic floods in Emilia Romagna in 2023

2023 Flood caused
- 16 casualties
- 23,000 displaced
- 21 rivers flooded
- 66,000 landslides
- 2,000 km road disrupted

▶ **Emergency Response**
- 600 employees Taskforce
- 200 industrial vehicles

▶ **Impact**
Partial traffic flow restored in 30 hours and full restoration in five days

▶ **Post-Event Assessment:**
- Identified damages of 13 km of barriers
- 50,000 km of paving
- 10 km of highway embankment

Restoration costs of US$ 12 million (2023)

Prompted immediate reinforcement of barriers, embankments, and road surfaces, while accelerated the integration of climate resilience into every facet of ASPI's operations.

Continuous innovation, proactive management, and strategic collaboration, exemplified by the Pilot Multistakeholder Regional Plan initiated after the Emilia Romagna flood, will drive ASPI's infrastructure into a resilient and sustainable future

Source: Based on BCG project Experience—Autostrade per l'Italia comprehensive Climate A&R Strategy (2023)

Enhancing the resilience of transport infrastructure to climate risks demands a lifecycle-oriented outlook. This will require embedding resilience considerations at every stage of a transport infrastructure project's lifecycle: Strategy, Planning & Design, Procurement, Construction, and Operations & Utilization, to the End of Life.

The need for this systemic methodology is undeniable. Resilience measures require foresight and integration from the earliest planning stages, as such changes often cannot be retrofitted mid-cycle. Consider the strategic placement of coastal highways to mitigate flood risks or the incorporation of heat-resistant materials in rail networks —decisions like these are crucial to be addressed in the initial design phase as they could have an impact on overall resilience of the asset in the future. National & subnational governments, public/ private infrastructure entities, financial institutions, thinktanks & all other relevant stakeholders must align their efforts throughout the project lifecycle to render infrastructure resilient.

By weaving resilience into every stage of the project lifecycle, a multiplier effect could be created that transcends the sum of individual interventions.

This holistic strategy not only shields our transport networks from immediate climate threats but also instils them with the resilience capacity to evolve in the face of future challenges, safeguarding their long-term viability and economic value.

Charting the course: Key questions needed to be collectively answered by all stakeholders across each stage of the lifecycle for Adaptation and Resilience (A&R) in infrastructure development.

To operationalize the lifecycle lens, stakeholders must ask critical questions at each stage of the project, steering decisions that enhance infrastructure durability and adaptability. (See Exhibit 5).

These critical considerations underscore the need for a holistic roadmap to resilience, emphasizing risk assessment, stakeholder collaboration, innovative design, and continuous monitoring throughout the infrastructure lifecycle. This integrated strategy sets the stage for a comprehensive framework that enhances the resilience of transport infrastructure, bridging current practices with innovative solutions.

Exhibit 5: Key Questions to Embed Resilience at Each Stage of the Transport Project Lifecycle

Strategy	• What are the resilience objectives and overall project goals? • What are the key geoclimatic risks and baseline of exposure associated with this infrastructure project? • What are the technologies that can be leveraged to assess exposure and vulnerability? • What metrics will be used to measure the effectiveness of the resilience strategy over time?
Planning & Design	• Which design interventions will most effectively contribute to risk reduction to improve resilience? • What are the applicable design standards to mitigate/ reduce disaster risks effectively? • How will innovative technologies and design interventions be sequenced to maximize resilience? • How are resilience finance and disaster insurance integrated into the project's financial plan?
Procurement	• How to determine risk appetite and contracting options for the entities issuing tenders? • How will disaster resilience criteria be integrated into the procurement process and protocol? • How will suppliers' following resilience practices be identified and onboarded? • What financial contingencies/ risk mitigation funds are planned to support resilience throughout procurement?
Construction	• How will disaster risks be assessed, managed, and monitored in real-time during construction? • How will resilient materials/ construction solutions be used to ensure infra. withstands geo-climatic hazards? • How will compliance with resilience plans and building codes be ensured on-site during construction? • How will construction timelines & personnel safety be ensured while maintaining resilience?
Operations & Utilization	• What strategies will be employed to ensure operational continuity during and after disaster events? • What technologies will be used to predict disasters & ensure continuity of operations during disasters? • How effective are the disaster response systems in maintaining operational functionality? • How will the resilience of operational systems be periodically tested and improved?
End of Life	• How can operational transport infrastructure be repurposed while maintaining resilience? • What can be done to address post-disaster loss and damage? • What resources will be allocated to sustain resilience through the end-of-life phase? • How will learnings from the lifecycle of the current project be integrated into future projects?

Source: BCG Analysis based on experience of transportation infrastructure projects (2024)

The Integrated Approach for Resilient Transport

A holistic framework integrating policy, technology, and finance, underpinned by robust governance and capacity building, is imperative for building climate-resilient transport systems in South Asia

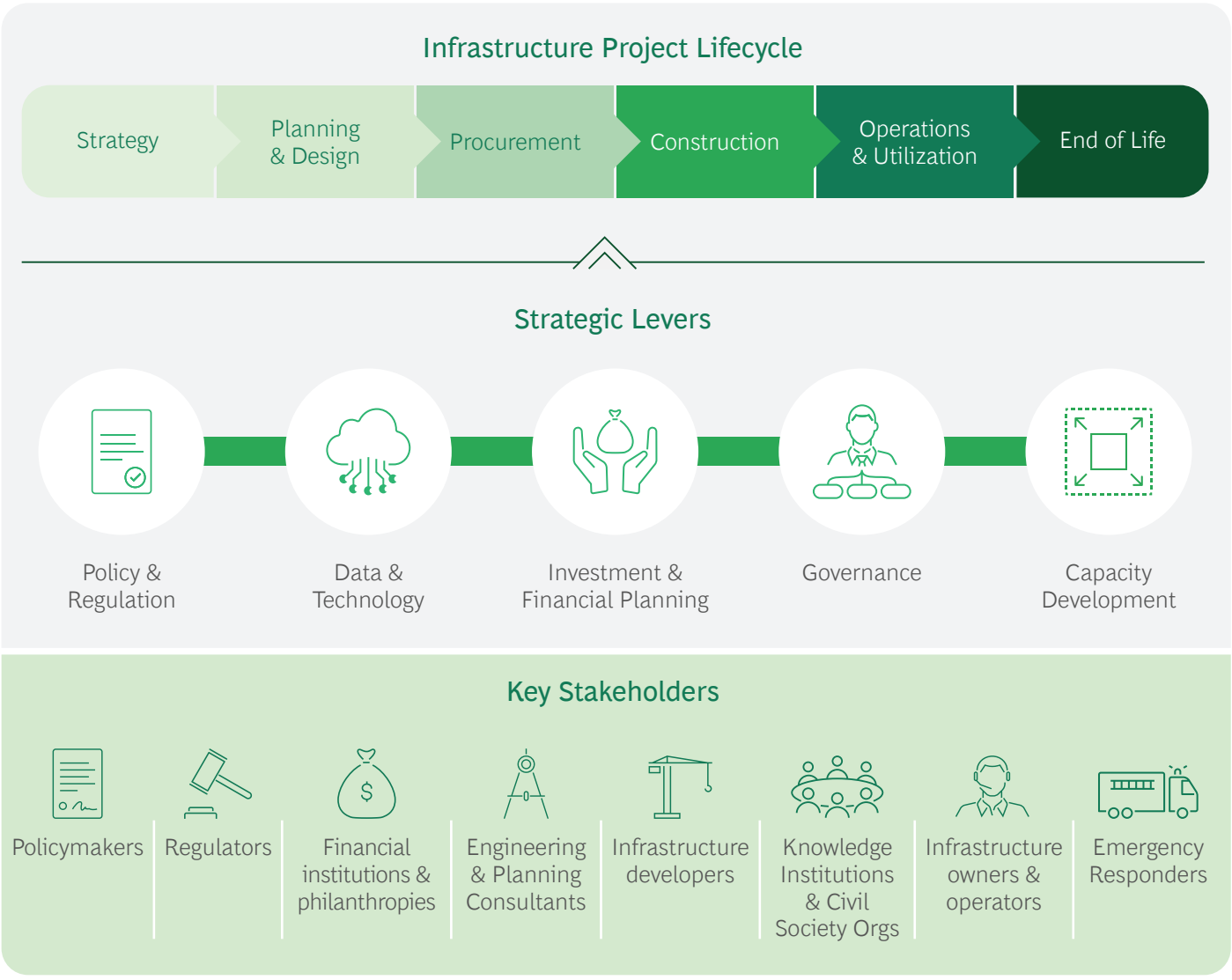
The significant challenges presented by climate change and geo-climatic hazards demand a fundamental reimagining of how we address transport infrastructure design, development, operations and post life phases.

While guidance for infrastructure resilience in the transport sector exists in parts, there is a need for an integrated approach—one that presents a unified model for embedding resilience across the entire project lifecycle

with strategic levers and diverse stakeholders. This interconnected framework should present a unified model for embedding resilience across every stage, from conception to completion and beyond. By placing resilience at the core of every decision, and fostering synergy between lifecycle phases, enabling levers, and key actors, we can create transport systems that are not only robust in the face of current climate threats but also adaptable to future challenges. This holistic vision ensures that resilience is not an afterthought or a reactive consideration, but a guiding force that permeates all aspects of infrastructure development and management. (See Exhibit 6)

Global practices which are considered good, suggest that to effectively fortify our transport systems, resilience measures need to encompass critical areas such as policy & regulation for ensuring consistent standards and accountability, data & technology for fostering accurate scientific risk modelling and innovation, and investment & financial planning to enable funding for bankable resilient projects. Additionally, strong governance and targeted capacity building are essential to ensure coordinated implementation and equip stakeholders with the skills needed to drive resilience throughout the project lifecycle. (See Exhibit 7)

Exhibit 6: Building Resilient Transport—Lifecycle Phases, Strategic Levers, and Stakeholder Roles



Source: BCG Analysis based on experience of transportation infrastructure projects (2024)

Exhibit 7: Strategic Enablers for Advancing Resilient Transport Infrastructure

Advancing Transport Infrastructure Resilience

Policy & Regulation

Establishes the regulatory framework and standards necessary for implementing resilient infrastructure, ensuring alignment with climate risk and criticality assessments.

SPOTLIGHT

Singapore

Singapore strengthened embedding of infrastructure resilience through adopting Eurocodes as sole structural standards in 2015, adapting them via National Annexes. The Building and Construction Authority's rigorous training bolstered infrastructure resilience & professional excellence in the region.

Source: Based on BCG project experience

Data & Technology

Leverages cutting-edge technology and data-driven decision-making to enhance infrastructure resilience through improved risk management and adaptive solutions.

SPOTLIGHT

Japan

Japan deployed an integrated framework of Mobile Mapping, fibre-optic sensors, and satellite analytics through the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT). This enhanced early detection of issues, optimizing maintenance and reducing costs for robust transport systems amidst escalating environmental risks.

Source: OECD (2024)

Investment & Financial Planning

Facilitates access to finance, innovative insurance solutions and financial incentives for risk reduction, enabling implementation of bankable resilience projects and ensuring long-term viability of infrastructure investments.

SPOTLIGHT

Philippines

Philippines mandated that 5 percent of national and local budgets be allocated for the Local Disaster Risk Reduction and Management Fund (LDRRMF) through Republic Act 10121. This critical fund allocates 70 percent to prevention, mitigation and preparedness, 30 percent to Quick Response Fund (QRF), bolstering infrastructure and capacity.

Source: Prepare Center (2013)

Governance

Ensures coordinated disaster resilience through cross-sector collaboration & adaptive policies across the infrastructure lifecycle. Establishes unified governance mechanisms to integrate risk & resilience, aligning projects with long-term goals and promoting cohesive responses to climate risks.

SPOTLIGHT

The Netherlands

The Netherlands showcased effective cross-sectoral government collaboration and stakeholder engagement through the Delta Programme, established to manage flood risks and freshwater supply. Bringing together central and local governments, water boards, and the Delta Commissioner, the programme employs adaptive delta management, integrating long-term planning with regular stakeholder feedback.

Source: Richard Judge & Arthur Petersen, Planned Adaptive Regulation–Learnings from the Delta Programme

Capacity Development

Drives resilience by empowering stakeholders with the necessary skills, tools, and knowledge to effectively plan, design, and implement resilient infrastructure. Facilitates training programs and certification processes to help bridge technical gaps, while fostering innovation and compliance with evolving resilience standards.

SPOTLIGHT

United States

United States, particularly California enforced stringent licensing and education requirements for architects in disaster resilience. Focusing on seismic safety, Zero Net Carbon, and Climate Resilient Design, this approach enhances expertise and ensures regulatory compliance, and keeps professionals updated on resilient design practices tailored to California's unique challenges.

Source: California Architects Board (2024)

SPOTLIGHT #3

The Global Infrastructure Risk and Resilience Index (GIRI)—Making Data on Infrastructure Resilience Globally Available

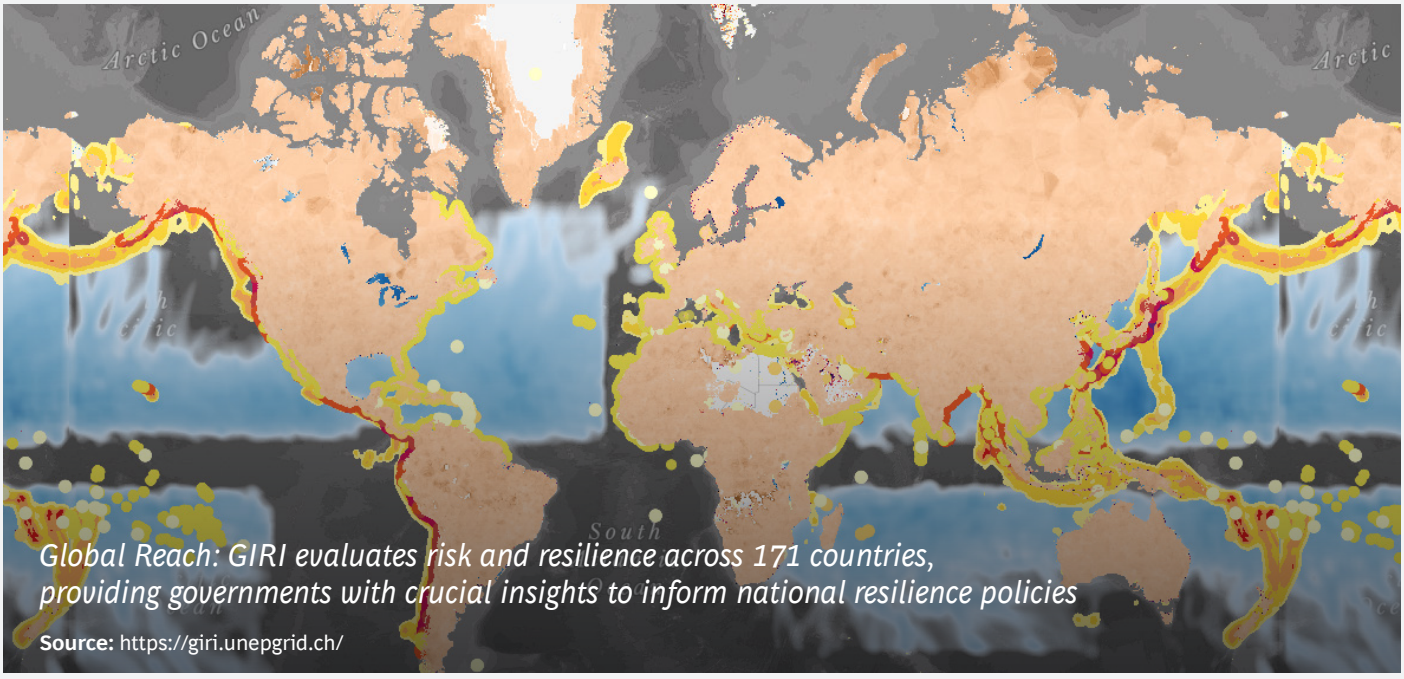
GIRI developed by CDRI, marks a transformative leap in disaster risk evaluation and resilience planning. Leveraging over two decades of global risk modelling expertise, GIRI integrates forward-looking climate data with traditional hazard assessments, providing a comprehensive and precise analysis of future risks.

Designed as a scalable platform, GIRI offers a robust foundation for assessing risks to critical infrastructure by estimating key metrics such as Average Annual Loss (AAL) and exposure levels.

Key Features

1. **Comprehensive Hazard Coverage:** GIRI addresses six critical geo climatic hazards while incorporating the impacts of climate change
2. **Multi-Sector Analysis:** Spanning nine vital infrastructure sectors, GIRI enables systemic risk assessment across interconnected networks
3. **Probabilistic Modelling:** Utilizing advanced modelling techniques, GIRI generates robust metrics such AAL and PML to guide strategic decision-making

Scalable Implementation: GIRI's platform is designed to ensure consistency from global to local levels, allowing for targeted interventions that are tailored to the specific needs of different regions. This ensures that resilience-building efforts are informed by precise, location-specific data.



Global Reach: GIRI evaluates risk and resilience across 171 countries, providing governments with crucial insights to inform national resilience policies

Source: https://giri.unepgrid.ch/

Impact and Potential

GIRI offers a powerful tool for transforming infrastructure vulnerability into strategic resilience, enabling precise investment prioritization and the development of robust infrastructure standards. Its global application, covering 171 countries, underscores its potential to drive significant cost savings and loss prevention worldwide.

As the urgency of climate threats intensifies, GIRI stands as an essential resource for nations seeking to secure a resilient future for their critical infrastructure.

Source: CDRI (2023)
Note: Average Annual Loss (AAL) and Probable Maximum Loss (PML)

Reliable climate science data & evidence is one of the most crucial enablers to ensuring resilient development of future transport infrastructure

Fostering continuous stakeholder collaboration is vital to orchestrate change for building resilience

The path to resilient transport infrastructure in South Asia calls for synergistic dialogue across all stakeholders at all three levels: regional, national and sub-national. Each stakeholder brings unique strengths and influence to unlock the resilience potential of transport infrastructure and despite the complexity of multi-level interactions, impactful and sustainable outcomes can be achieved by strategically leveraging these strengths. (See Exhibit 8)

At the core of this resilient transport infrastructure ecosystem lie two crucial accelerators: capacity development and governance. These could serve as the foundational pillars that enable and enhance the effectiveness of all stakeholders and facilitate the execution of resilience measures. Capacity development

Exhibit 8: Key Actors in Transport Infrastructure Resilience

Source: BCG Analysis based on experience of adaptation and resilience in transportation infrastructure projects (2024)

ensures that actors across the spectrum are equipped with the necessary skills, knowledge, and resources to contribute effectively to A&R efforts. Concurrently, comprehensive governance frameworks offer the structure, coordination, and accountability necessary to unify diverse initiatives toward shared resilience objectives. This collaborative ecosystem, with capacity development and governance as its nucleus, facilitates:

Knowledge sharing and skill enhancement

Policy alignment and regulatory harmonization

Development, piloting and scaled implementation of best practices

Innovation in resilience technologies and methodologies

Each stakeholder plays differentiated yet interlinked roles in this context, from establishing regulatory frameworks and providing financial support to offering technical expertise and driving innovation. By placing these accelerators at the centre, we ensure not only that all actors are well-equipped, but also that their efforts are well-coordinated and directed towards creating truly resilient transport infrastructure across the life cycle – from strategy and planning through to end-of-life.

Navigating the path towards a lifecycle approach to resilience in transport infrastructure necessitates an intricate and cohesive framework.

Forging an ecosystem that effectively mobilises stakeholders across the infrastructure project lifecycle is a must for developing climate and disaster resilient transport systems

As transport networks continue to face growing climate risks, the current methods fall short in advancing resilient transport infrastructure, as coordination across stakeholders remains a challenge. While at a fundamental level, the effectiveness of actions depends on factors such as the technology deployed, funding available, investment structure for the infrastructure, and the industry policy, codes and standards. Strengthening capacity development and governance remain some critical unlocks which drive stakeholder alignment to implement the resilience plans. To meet the pressing challenges that climate change poses to our transport infrastructure, all stakeholders must adapt to more comprehensive frameworks of project design, delivery, and management. This is imperative for securing the future of South Asia's critical transport networks and the economies they support.

Consider the current landscape: risk assessments remain sporadic and fail to inform critical infrastructure decisions of siting, financing and operating. Regulatory frameworks need to keep up with the rapidly evolving climate realities, to secure projects vulnerable to future shocks. The knowledge gap between cutting-edge resilience strategies and on-the-ground implementation continues to widen, while financial mechanisms struggle to keep pace with the scale of investment required for building resilience. By integrating policy, technology, and finance with robust governance and capacity development, a synergistic ecosystem can be created that addresses current shortcomings and anticipates future challenges. (See Exhibit 9)

Exhibit 9: Integrated Framework for Infrastructure Resilience in Transport (I/II)

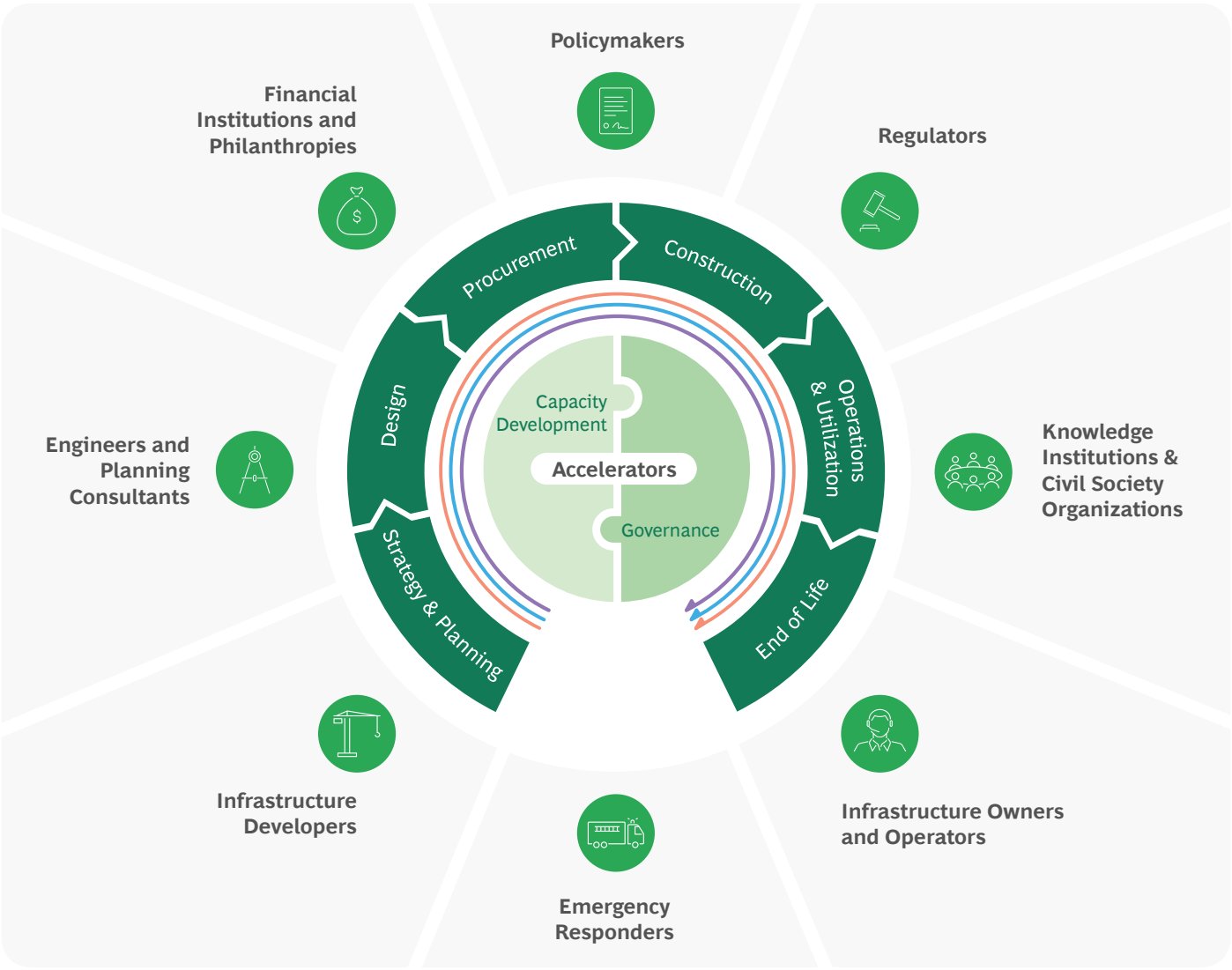


Exhibit 9: Integrated Framework for Infrastructure Resilience in Transport (II/II)

Key considerations in the Infra Project Lifecycle

Strategy	Planning & Design	Procurement	Construction	Operations & Utilization	End of Life
Define A&R objectives & interdepend-dencies	Secure approvals in compliance with A&R standards & codes	Determine risk appetite and options for contracting	Build as per construction norms embedding resilience	Maintain network & operations modelling for regular scenario prediction	Evaluate climate impact induced end of life risks for assets
Conduct exposure & vulnerability analysis	Create resilient design	Promote procurement of resilient materials & suppliers	Deploy contingency plan including resilience	Install monitoring sensors & early warning systems	Assess options to safely recycle, re-purpose or re-use materials
Assess cost of inaction v/s res. investment					

Ecosystem Enablers for Building Resilience

Policy & Regulation

- Mandate scans for risk assessment and resilience planning in all transport developments
- Launch post disaster loss & damage evaluation framework
- Mandate monitoring for adherence to climate resilience plans
- Establish resilience construction codes & standards based on climate risk criticality & urgency
- Design operating manuals embedding resilience for adherence across project lifecycle
- Develop guidelines to facilitate procurement of resilient materials & suppliers

Data & Technology

- Deploy data & tech for geo-climatic risk assessments
- Incorporate innovative design technology to embed adaptive capacity
- Implement real-time impact monitoring & advanced analytics for monitoring, reporting & evaluation
- Design standard operating procedures to deploy rapid response measures

Investment & Financial Planning

- Create business case to embed resilience in transport project portfolio
- Design & test A&R financing mechanisms including innovative insurance, alternative funding sources & incentives for risk reduction
- Develop shared resilience taxonomies to facilitate varied financing options
- Monitor continuous resilience spending across project lifecycle

Accelerators

Governance

- Establish cross-sector governance units to coordinate A&R strategies for transport infrastructure
- Implement responsive & adaptive governance practices to fortify transport infrastructure against evolving climate threats
- Update transport infrastructure, policies, frameworks & regulations periodically to reflect the evolving climate context

Capacity Development

- Develop qualification norms for practitioners for resilient infrastructure design and management
- Conduct training, assessment & accreditation facilitation for resilience professionals including designers & engineers
- Cultivate a global network of resilience professionals to accelerate knowledge sharing and best practices

Lead Stakeholder Relevance:

● National and Subnational Governments ● Public/Private Infrastructure Entities ● Financial Institutions ● Institutions and thinktanks

Source: BCG Analysis based on research and consultations conducted for the publication (2024)

The integrated framework provides a comprehensive roadmap for embedding resilience throughout the transport infrastructure lifecycle. It outlines targeted interventions adaptable to project scope and regional context, addressing critical gaps in current practices. The framework identifies key focus areas requiring immediate attention while aligning priorities to support the entire infrastructure lifecycle. It offers clear guidelines for stakeholder collaboration, informing diverse actors including governments, infrastructure entities, financial institutions, and knowledge centers. By coordinating efforts across these ecosystem enablers, the framework transforms challenges into opportunities for innovation and resilient growth. This approach maximizes the impact of interventions, accelerating the transition to sustainable and resilient transport infrastructure in South Asia.

The Way Forward: Call to Action for Mobilizing Resilient Transport Infrastructure

Coordinated, decisive efforts across all stakeholders are crucial to create sustainable and disaster resilient infrastructure

Embedding resilience into transport infrastructure calls for a cohesive strategy that spans six key target areas, ensuring that resilience is integrated at every stage. National and subnational adaptation and resilience plans lay the groundwork for assessing risks and setting measurable targets, which in turn inform the establishment and enrichment of comprehensive codes and standards for both new and existing infrastructure. These plans facilitate climate risk assessments at the earliest stages of project planning,

shaping decisions and priorities. By incorporating resilience into procurement, projects align with climate-readiness requirements, while professional development ensures a skilled workforce capable of managing resilient systems. Finally, innovative financial mechanisms like green bonds, public-private partnerships, and climate risk insurance enable the scaling of these efforts, creating a holistic framework that fosters long-term resilience across South Asia's transport infrastructure. (See Exhibit 10)

Every stakeholder has a vital part to play in crafting a resilient, prosperous future for the region. By assigning potential 'Anchors' to lead and drive initiatives, and potential 'Collaborators' to provide crucial support and expertise, this approach promotes synergistic stakeholder engagement, ensuring that national and subnational governments, private and public infrastructure entities, financial institutions, and knowledge centres all play pivotal roles in powering this transformation.

Exhibit 10: Six Calls To Action to Drive Resilience across South Asia's Transport Infrastructure (I/II)

		Anchor	Collaborators
1	**Develop national & subnational adaptation & resilience plans with measurable targets covering transport infrastructure**		
	Develop comprehensive national and subnational resilience plans with measurable targets, outlining key goals and strategies	National and Subnational Governments	Public/Private Infrastructure Entities
	Devise a classification system for climate hazard vulnerability assessment, tailored to South Asian context	National and Subnational Governments	Public/Private Infrastructure Entities
	Ensure dedicated coverage of transport infrastructure resilience in city/ state/ national adaptation plans & strategies, including quantified resilience targets based on respective country contexts	National and Subnational Governments	Institutions and Thinktanks
2	**Mainstream climate risk assessments in prefeasibility stage of greenfield and brownfield infrastructure projects**		
	Create a comprehensive subnational & national repository of climate and hazard data relevant to transport infrastructure	National and Subnational Governments	Public/Private Infrastructure Entities
	Develop a national physical risk platform to facilitate access for infrastructure stakeholders to latest scientific data and models, utilizing localized studies	National and Subnational Governments	Public/Private Infrastructure Entities
	Generate a South Asia specific-adaptable Climate Resilience Assessment (CRA) methodology to: a) Quantify inaction costs b) Evaluate potential co-benefits c) Prioritize transport project investments	National and Subnational Governments	Institutions and Thinktanks
	Leverage artificial intelligence and predictive analytics in transport sector for enhanced loss quantification accuracy	Public/Private Infrastructure Entities	Institutions and Thinktanks
3	**Establish comprehensive transport infrastructure codes and standards for embedding resilience**		
	Strengthen resilience parameters in existing codes, mandating forward-looking climate data use for design parameters in new and existing transport infrastructure at national and subnational levels	National and Subnational Governments	Public/Private Infrastructure Entities
	Harmonize resilience standards for new and existing transport infrastructure projects across all government levels	National and Subnational Governments	Public/Private Infrastructure Entities
	Devise a rating system for transport infrastructure components utilizing & enriching publicly available data	Public/Private Infrastructure Entities	National and Subnational Governments

National and Subnational Governments · Public/Private Infrastructure Entities · Financial Institutions · Institutions and Thinktanks

Exhibit 10: Six Calls To Action to Drive Resilience across South Asia's Transport Infrastructure (II/II)

	Anchor	Collaborators
4 Incorporate resilience in procurement for infrastructure projects		
Mandate climate risk assessments, certified by reputable and empanelled agencies, for all major transport infrastructure projects exceeding specified thresholds		
Integrate requirements such as inclusion of high-performance materials and enhanced structural specifications in Detailed Project Reports (DPRs) for high-risk zones		
Implement mandatory resilience qualifications for professionals, in bid documents and formalize resilience-enabled Standard Operating Procedures (SOPs) for biannual operations and maintenance in vendor contracts		
5 Embed resilience topics within the current skill & capacity enhancement, training & license certification mechanisms		
Introduce mandatory disaster resilience modules in licensing requirements for engineers and architects to ensure expertise in designing infrastructure resilient to local disaster risks		
Implement Continuing Education (CE) requirements focused on disaster resilience and sustainability to ensure licensed professionals maintain relevant skills and knowledge		
Design & implement targeted resilience training opportunities for all professionals across the project lifecycle		
6 Enhance availability & access to finance for resilience in transport infra projects		
Develop a pipeline of prioritized, localized & bankable resilience projects in transport infrastructure through adequate public private partnerships		
Explore blending of finance from multiple sources such as public funds, private investment, and international climate finance to address the finance gap in transport resilience		
Engage insurers to take a central role in derisking and enhancing businesses' climate risk understanding, guaranteeing multi-year insurance availability and capacity		

 National and Subnational Governments

 Public/Private Infrastructure Entities

 Financial Institutions

 Institutions and Thinktanks

Source: BCG Analysis based on experience of adaptation & resilience in transportation infrastructure projects (2024)

The present moment calls for purposeful and transformative efforts. Now, governments, companies and financiers must rise to the challenge, to shape infrastructure of the future, that is resilient and adapted to the irreversible impacts of climate change. South Asia has the opportunity to channel climate considerations as catalysts for innovation and sustainable development. **The time for decisive action is now.**

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About the Authors

Authors

Anirban Mukherjee
Managing Director and Partner, BCG
Mukherjee.Anirban@bcg.com
New Delhi, India

Vineet Vijayavargia
Managing Director and Partner, BCG
Vijayavargia.Vineet@bcg.com
New Delhi, India

Annika Zawadzki
Managing Director and Partner, BCG
Zawadzki.Annika@bcg.com
Cologne, Germany

Ashish Kulkarni
Partner and Associate Director, BCG
Kulkarni.Ashish@bcg.com
New Delhi, India

Tania Banerjee
Associate Director, BCG
Banerjee.Tania@bcg.com
New Delhi, India

Contributors

Ranjini Mukherjee
Director-Research, Knowledge Management
& Capacity Development, CDRI
Ranjini.M@cdri.world
New Delhi, India

David White
Director-Advocacy and Communications, CDRI
David.White@cdri.world
New Delhi, India

Dr. Abhijit Datey
Lead Specialist-Research, CDRI
Abhijit.Datey@cdri.world
New Delhi, India

Kiran Gowda
Advisor-Transport, CDRI
Kiran.Gowda@cdri.world
New Delhi, India

Sakshi Dasgupta
Lead Specialist-Technical Studies, CDRI
Sakshi.Dasgupta@cdri.world
New Delhi, India

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For Further Contact

If you would like to discuss this report, please contact the authors.

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