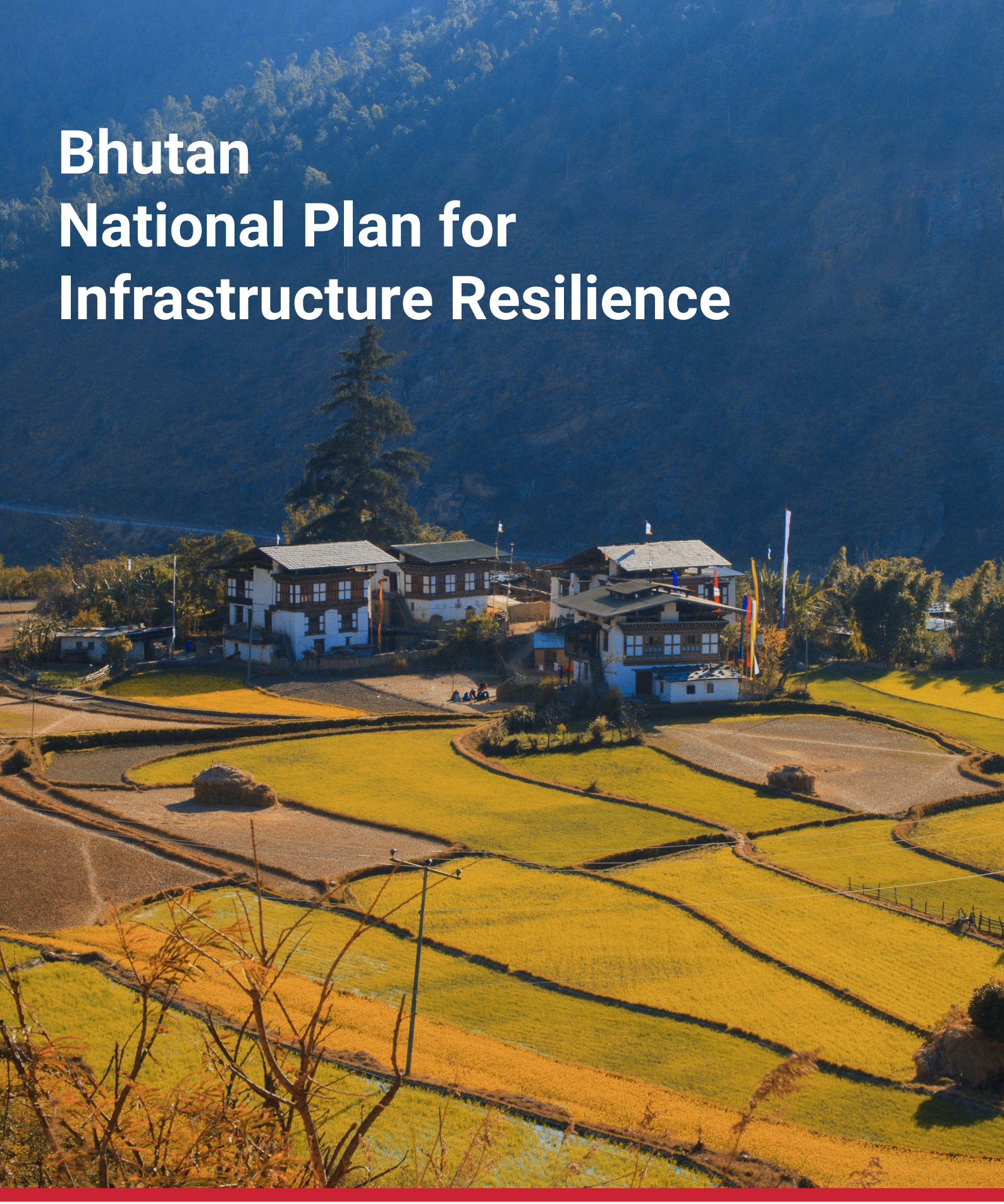
# Bhutan National Plan for Infrastructure Resilience



*Royal Government of Bhutan*

*In collaboration with:*

UNDRR UN Office for Disaster Risk Reduction

CDRI Coalition for Disaster Resilient Infrastructure

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **AI** | Artificial Intelligence |
| **ASCE** | American Society of Civil Engineers |
| **ATC** | Air Traffic Control |
| **CCA** | Climate Change Adaptation |
| **CDRI** | Coalition for Disaster Resilient Infrastructure |
| **CGISC** | Centre for GIS Coordination |
| **BtCIRT** | Bhutan Computer Incident Response Team |
| **CNDP** | Comprehensive National Development Plan |
| **DM** | Disaster Management |
| **DMCP** | Disaster Management and Contingency Plan |
| **DMIS** | Disaster Management Information System |
| **DRM** | Disaster Risk Management |
| **DRR** | Disaster Risk Reduction |
| **ECCD** | Early Childhood Care and Development |
| **EIA** | Environmental Impact Assessment |
| **EWS** | Early Warning System |
| **FYP** | Five Year Plan |
| **GDP** | Gross Domestic Product |
| **GEM** | Global Earthquake Model |
| **GIS** | Geographic Information System |
| **GLOF** | Glacial Lake Outburst Flood |
| **GPS** | Global Positioning System |
| **IMTF** | Inter-Ministerial Task Force |
| **ISP** | Internet Service Provider |
| **IWRM** | Integrated Water Resource Management |
| **MHRDSS** | Multi-Hazard Risk Decision Support System |
| **NAP** | National Adaptation Plan |
| **NDMA** | National Disaster Management Authority |
| **NDRMS** | National Disaster Risk Management Strategy |
| **NEOC** | National Emergency Operation Centre |
| **PGA** | Peak Ground Acceleration |
| **PPE** | Personal Protective Equipment |
| **PPP** | Public Private Partnership |
| **PSMP** | Power System Master Plan |
| **RWSS** | Rural Water Supply Scheme |
| **SCADA** | Supervisory Control and Data Acquisition |
| **SOP** | Standard Operating Procedure |
| **UNDRR** | United Nations Office for Disaster Risk Reduction |
| **UNOSAT** | United Nations Satellite Centre |
| **WASH** | Water, Sanitation and Hygiene |
| **WASIS** | Water and Sanitation Information System |

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# Executive Summary

## NATIONAL PLAN FOR INFRASTRUCTURE RESILIENCE IN BHUTAN

**The National Plan for Infrastructure Resilience in Bhutan is a roadmap for enhancing the resilience of critical infrastructure sectors against natural and human-made hazards.** The Plan was developed by the Technical Working Group for Infrastructure Resilience led by the Department of Local Governance and Disaster Risk Management (DLGDM) under the Ministry of Home Affairs through collaboration with the United Nations Office for Disaster Risk Reduction (UNDRR) and the Coalition for Disaster Resilient Infrastructure (CDRI), and with support from the United Nations Satellite Centre (UNOSAT). This National Plan resulted from a participatory approach to identifying vulnerabilities in infrastructure sectors, understanding and assessing the risks to which they are exposed, and recommending actionable measures for enhancing resilience in critical infrastructure systems. The proposed National Plan provides a strategic guide for policymakers, government agencies, and other stakeholders in Bhutan.

**The approach for developing the plan follows the stages outlined in the Global Methodology for Infrastructure Resilience Review (GMIRR) developed by UNDRR and CDRI.** The core methodological components include a detailed mapping of institutional governance and policy frameworks related to infrastructure development and Disaster Risk Reduction. Alignment with the Principles for Resilient Infrastructure is used to assess the country's current state of infrastructure resilience, identify gaps and areas for improvement, and prioritize actions. In addition, a stress-testing exercise was conducted to identify vulnerabilities in infrastructure systems and service interdependencies, including potential cascading effects.

**The process engaged 21 agencies across seven ministries, with analysis and recommendations developed by key infrastructure stakeholders in Bhutan,** supported by international experts. This collaborative effort resulted in both cross-sectoral and sector-specific recommendations, consolidating the findings into a comprehensive National Plan for infrastructure resilience. The plan was validated through stakeholder workshops and consultations, ensuring broad support and alignment with national priorities. The recommendations were developed to support Bhutan's 13th Five Year Plan and will be used by the sectors to develop their action plans.

**The National Plan for Infrastructure Resilience focuses on cross-sector governance and covers six infrastructure sectors** -transport (road and aviation), energy (hydropower), water, and information and communication technology (ICT)- which play a key role in the country's economic structure. Health and education were also assessed at the request of stakeholders due to their systemic importance to the social sector. Within these sectors, ten critical infrastructure functions were analysed in more detail, including by reviewing their connections to ten key economic industries of importance to Bhutan's economy; and by considering ten particularly important hazards.

## KEY FINDING FROM THE CROSS-SECTOR ANALYSIS

Bhutan's institutional and policy framework for Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) is in place. The inter-sectoral mechanism for DRR and CCA in Bhutan is built on key policy instruments and strategies including the Disaster Management Act 2013, Climate Change Policy 2020, the National Adaptation Plan (NAP) and Disaster Risk Management Plans. The Five Year Plans continue to integrate disaster and climate resilience within Bhutan's broader development objectives.

Nonetheless, the following actions are needed to further strengthen infrastructure resilience:

- Updating cross-sector infrastructure codes and regulations to incorporate climate and disaster resilience.
- Strengthening governance to improve coordination, which includes defining critical infrastructure sectors and establishing a dedicated multi-sector technical task force to advice DRR and resilience.
- Addressing key technical capacity gaps in Geographic Information System (GIS), remote sensing, surveying, and climate resilient infrastructure design that are essential for better multi-sector planning.
- Creating a national database to track critical infrastructure systems and performance, facilitating data sharing among stakeholders, and improving decision-making and infrastructure services continuity.

## KEY FINDING FROM THE SECTOR ANALYSIS

### Transport Sector

Bhutan's transport sector, which includes road and air transport, is vital to the country's socio-economic development. The stress test analysis identified landslides as the most significant threat to road and bridge infrastructures in Bhutan, often triggered by heavy monsoon precipitation and weak geological foundations leading to slope failures. Earthquakes and windstorms emerge as the most significant threats to air transport. Floods, including flash floods and riverine floods, also present considerable risks to airport assets and their related services along the river banks. Both road and air transport infrastructure is also highly dependent on other critical services, such as electricity, water, ICT, and health systems. Disruptions in these support services could result in cascading failures that

compound the impact on the transport sector.

### Energy Sector

Bhutan's energy sector is predominantly powered by hydropower generation, which serves as the backbone of the economy, contributing to 25% of the government's revenue and approximately 7.5% of the nation's GDP. The stress test analysis identified Bhutan's run-of-the-river hydropower plants as highly vulnerable to climate change-induced droughts, Glacial Lake Outburst Floods (GLOF), and increased sedimentation, with the country's mountainous terrain and seismic activity further exacerbating risks. Additionally, the Transmission and Distribution (T&D) network is particularly susceptible to geological events, fires, and flash floods, posing risks of electrical failures and extended power disruptions. The energy sector is also highly dependent on road and surface transport regarding access to maintain its assets. The energy sector is also dependent on water supply and ICT. Any disruptions in these would have cascading impacts on the electricity supply and other critical functions that are dependent on its services.

### Water Sector

Water is a significant economic driver in Bhutan, supporting key sectors such as agriculture, hydropower, tourism, and other water-related industries. The stress test analysed water supply treatment and distribution and wastewater management as two critical functions of the water sector. It identified drought as the most significant risk to water supply, impacting agriculture, hydropower generation and other water-dependent industries, and health outcomes. Existing water infrastructure requires resilience improvements to meet current and future demand. Additionally, Bhutan's water systems are interdependent on other sectors, such as electricity and transportation, and disruptions in these sectors could affect water supply and management. Water quality is also at risk from unmanaged wastewater seepage, agricultural runoff, and contamination from floods and landslides.

### Information, Communication and Technology Sector

ICT plays a critical role in addressing national development priorities given the country's challenging geography and multi-hazard landscape. Cybersecurity breaches are identified as the most significant threat for this sector, exacerbated by a lack of expertise in managing the risks. Hazards, such as earthquakes and landslides, pose additional risks to ICT infrastructure and assets. The stress test analysis also demonstrated that the sector has a high dependence on energy supply, with medium dependencies on water supply, wastewater management, and transport services. Meanwhile, disruptions to ICT services, particularly internet routing and access, can have cascading effects on other sectors, impacting essential services including healthcare, water supply, financial activities and public administration.

### Education Sector

The stress test analysis focused on building and maintaining schools as critical functions of the education sector. It identified both infrastructure and occupants as highly vulnerable to earthquakes, landslides, structural fires, and epidemics, with flooding posing a medium risk. Many schools, especially non-engineered and community-built structures, are at high risk from earthquakes and cascading effects. Windstorms have become a recurrent hazard affecting schools in recent years.

Additionally, the sector is highly dependent on essential infrastructure, including water supply, electricity, road transport, and ICT. Any disruption in these services could significantly impair educational continuity and exacerbate vulnerabilities. Remote schools are particularly affected by limited accessibility and communication, further increasing their risk.

### Health Sector

Bhutan's health sector is highly vulnerable to hazards such as earthquakes, fires, landslides, and epidemics. All 149 health facilities in the country are exposed to high seismic risk, as evidenced by past health infrastructure losses and damage. The sector also faces persistent challenges from communicable, non-communicable, and zoonotic diseases, which are exacerbated by climate change. Health equity disparities between urban and rural areas result in unequal access to healthcare, less favourable health outcomes, and increased vulnerabilities. Additionally, health services rely heavily on water supply, electricity, ICT services, and transportation. Any disruptions in these areas could significantly impact healthcare operations, highlighting the need for resilient and well-integrated support systems.

## SUMMARY OF RECOMMENDATIONS

Based on the gaps identified throughout the analysis, a series of strategic recommendations has been proposed to improve the resilience of critical infrastructure systems and ensure sustainable development across key sectors. Table 1 shows a summary of the recommendations:

*Table 1. Consolidated recommendations*

| TYPE OF RECOMMENDATION | RECOMMENDATION |
|---|---|
| **POLICY & REGULATION** | There is a need to improve the mainstreaming of DRR and CCA across all sectors by drafting comprehensive guidelines and integrating performance indicators into sectoral plans; update building codes and land-use plans to include multi-hazard risk assessments and resilience measures; formulate a DRR financing strategy by incorporating risk transfer mechanisms; and establish clear urban transport frameworks integrating sustainable mobility and resilience criteria for infrastructure development. |
| **CAPACITY BUILDING** | Enhance technical capacity across sectors, particularly in hazard and risk assessments on seismic and landslide mapping, and the use of advanced technologies like GIS and remote sensing; provide targeted training to local government engineers, planners, and stakeholders on implementing monitoring frameworks for roads, water management, and disaster resilience; build capacity for environmental safety, cyber resilience, and safety standard compliance in sectors like ICT, health, and energy. |
| **DATA & ASSESSMENT** | There is a need to improve data sharing particularly on infrastructure exposures and system performance that includes stress testing of critical infrastructure, for data-informed decision-making; develop a centralised, interoperable data-sharing platform for cross-sector collaboration and real-time monitoring, and enhance the capability to respond to emerging risks. |
| **MONITORING & COMPLIANCE** | Establishing a monitoring framework for critical infrastructures such as water, road, and energy infrastructure, integrating real-time data collection and predictive maintenance technologies, is critical. It is needed to conduct regular audits and stress tests on infrastructure to ensure resilience, particularly in the health and education sectors. Strengthening environmental monitoring and compliance, particularly for ICT-related e-waste management and sustainable procurement practices, stands out. |
| **GOVERNANCE & COORDINATION** | There is a need to strengthen governance and coordination frameworks for infrastructure resilience through multi-sector technical task forces, improve collaboration between agencies and local governments to develop integrated master plans for utility services and ensure alignment of budgets and work plans. For international collaboration, the plan recommends reviewing existing agreements as well as exploring channels and third-party mediation for transboundary water management and disaster risk reduction. |

## PRIORITIZED RECOMMENDATIONS

After analysing and discussing the recommendations, stakeholders prioritized the following actions based on national resilience objectives and specific sectoral needs, ensuring alignment with the sector priorities outlined in the Five-Year Plan. A key outcome of this assessment is the agreement across sectors to integrate these recommendations into their respective action plans for the Five-Year Plan.

*Table 2. Priority actions by sector*

| SECTOR | PRIORITY RECOMMENDATION |
|---|---|
| CROSS SECTOR | Integrate critical infrastructure multi-hazard risk assessments, stress testing and resilience measures across sectors. |
| | Enhance critical infrastructure resilience governance through coordinated mechanisms and commitments. |
| | Enhance data sharing across infrastructure sectors to improve cross-sectoral collaboration for infrastructure planning and decision-making. |
| TRANSPORT | Infrastructure design & upgrades: using new technologies, stronger materials, elevated structures, permeable pavements. |
| ENERGY | Enhance compliance with safety standards of BPC/BSB by standardizing and establishing mechanisms to ensure safety code alignment. |
| WATER | Enhance the capacity of local governments in water and wastewater management. |
| ICT | Establish cyber resilience framework and expertise. |
| HEALTH | Establish & train a pool of mobile EMTs to respond quickly to emergencies. Establish formal agreements with neighbouring countries or INGOs to support emergency response. |
| EDUCATION | Establish a monitoring system that tracks the condition of school infrastructure and identifies potential hazards in real-time. |

*ESTABLISHING A NATIONAL PLAN FOR INFRASTRUCTURE RESILIENCE IN BHUTAN: A METHODOLOGICAL APPROACH*

# PART I. INTRODUCTION & METHODOLOGICAL APPROACH

The National Plan for Infrastructure Resilience in Bhutan is based on the Global Methodology for Infrastructure Resilience Review (GMIRR), a structured approach for infrastructure resilience reviews developed by the United Nations Office for Disaster Risk Reduction (UNDRR) and the Coalition for Disaster Resilient Infrastructure (CDRI). This methodology employs a participatory approach to review the alignment of existing policies and legislation with the Principles for Resilient Infrastructure to identify gaps, conduct stress testing to uncover risks and vulnerabilities of infrastructure systems and assess current governance practices of infrastructure resilience.

**KEY METHODOLOGICAL COMPONENTS ARE:**

Mapping of institutional governance and policy review: This required identifying key stakeholders in infrastructure development, disaster risk reduction, and sectoral operations, followed by a review of existing policies and regulations to assess their adequacy in addressing disaster risks and supporting resilient infrastructure systems.

Stress testing and gap analysis, were conducted on ten critical infrastructure functions to identify vulnerabilities, interdependencies, and cascading risks through the following steps:

- Identification of key sectors and critical functions: This process highlighted the critical role of infrastructure functions in maintaining the country's functionality and supporting its socio-economic development.
- Hazard and risk profiling: A list of relevant hazards was identified and assessed considering their historical impacts as well as the likelihood and potential impacts of each hazard, particularly in the context of climate change.

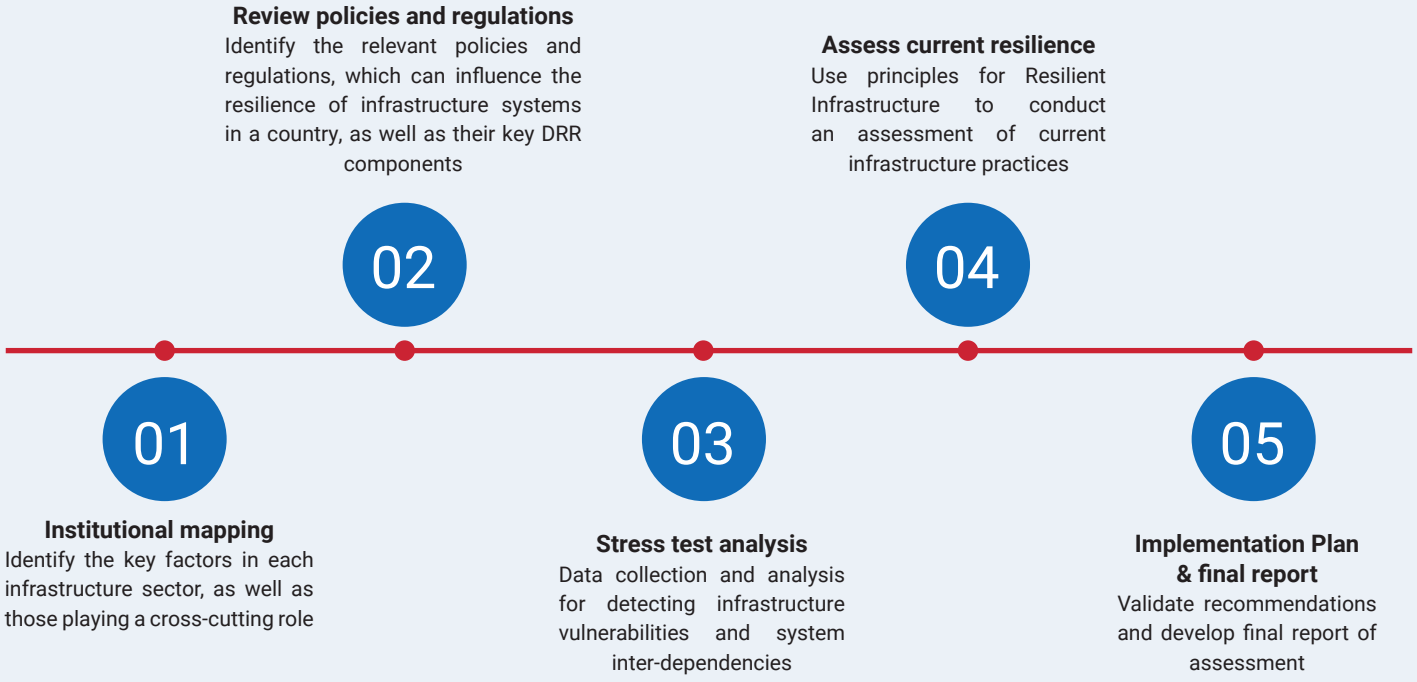
- Economic impact and linkages: The analysis extended to the relationship between infrastructure services and key sectors of the Bhutanese economy. By understanding how infrastructure functions support economic activities, the methodology provides insights into how disruptions in infrastructure services can propagate through the economy, affecting industries such as agriculture, manufacturing, and other key sectors.

- Interdependencies and risks analysis: Recognizing that the failure of one system can trigger failures in others, the emphasis on analysing interdependencies among infrastructure systems helps to enhance understanding and support the development of risk mitigation plans.

Assessment of current resilient infrastructure practices using Principles for Resilient infrastructure: The methodology is anchored in globally recognized principles for resilient infrastructure developed by UNDRR and consulted with over 100 countries. The principles guide policymakers to adopt resilient practices tailored to Bhutan's unique risk landscape.

Implementation Plan and roadmap: The entire process culminates in the drafting of implementation plans, consolidating the findings, and providing a roadmap for enhancing infrastructure resilience. The plan is validated through a stakeholder workshop and consultations to ensure broad support and alignment with national priorities.

*Figure 1. Methodological approach to infrastructure resilience*




# Institutional Mapping

**The first component of institutional mapping is to review the institutional arrangements, their mandates and functions, roles and responsibilities, and draw a list of the main infrastructure actors in the country that can have an impact on disaster risk reduction and climate change adaptation.** The review looked at cross-cutting sectors along the lines of DRR responsibilities, cross-sectoral coordination for infrastructure systems, and planning that include zoning and land-use plans, and critical infrastructure networks. The sector-wise institutional mapping was carried out along four major functions of an entity:

- **Policymakers** (often the Government) can initiate changes to national policy for infrastructure resilience, allocate the necessary funding to resilience-building activities, and require that the tendering process for infrastructure projects give appropriate weighting to resilience considerations.

- **Regulators** can monitor disruptions to critical services, ensure adherence to codes and standards, require operators to improve their resilience and introduce obligations on infrastructure operators to develop and maintain long-term resilience strategies.

- **Operators** can monitor their capacity to absorb disruptions caused by different types of hazards and retrofit improvements that improve their ability to absorb future ones.

- **Owners** can raise infrastructure-resilience standards, invest in skills and capacity to achieve infrastructure resilience and require operators to assess potential hazards.

# Policy and Regulatory Review

**The second component involved reviewing policy and regulatory frameworks on disaster risk reduction and climate change adaptation in relation to infrastructure.** The adequacy of policy and regulations for DRR within sectors as well as cross-cutting themes, directly determine the quality of assets and services, the effectiveness of public spending, and the incorporation of resilience measures. This review process, therefore, aims at identifying the relevant policies and regulations, which can influence the resilience of infrastructure systems in a country, as well as their key DRR components.

A number of key cross-cutting policy frameworks and sector-specific plans were reviewed and analysed to identify priority gaps and recommendations.

*Image from flood-hit Ungar village. Photo: Kuensel*

# Stress Testing and Identifying Critical Infrastructure Functions

**The third component to develop the national infrastructure resilience plan is conducting a stress testing analysis on ten critical infrastructure functions to identify vulnerabilities and interdependencies.** Critical infrastructure functions were selected for analysis based on the country's context and needs. They were identified from the primary infrastructure sectors (energy, transport, water, and ICT), and the health and education sectors because of their systemic importance to the Bhutanese social sector. These sectors perform a series of essential functions, ten of which were evaluated as part of a stress testing exercise:

- Supply, treat, and distribute water
- Manage wastewater
- Transport cargo and passengers by air
- Transport cargo and passengers by road
- Build and maintain roads, bridges and tunnels
- Generate electricity
- Transmit and distribute electricity
- Provide internet routing, access, and connections
- Build and maintain school facilities
- Build and maintain healthcare facilities

# A. Identifying Hazard and Risk Profiles

**The stress test analysis included selecting and analyzing the ten most relevant hazards to evaluate how infrastructure functions respond to multiple hazards simultaneously.** A "hazard" refers to any process, phenomenon, or human activity that can lead to loss of life, injury, property damage, social and economic disruption, or environmental degradation. When selecting the most relevant hazards for Bhutan, the likelihood and potential impacts, including how climate change may intensify these risks, were considered and discussed with the relevant stakeholders.

*Table 3. Ten hazards relevant to Bhutan and their impacts on key sectors*

| HAZARDS | IMPACTS |
|---|---|
| RIVERINE AND FLASH FLOODS | Over 70% of human settlements and crucial infrastructure are vulnerable to flooding. Changes in precipitation patterns are expected to increase the frequency and intensity of floods, with potentially damaging and life-threatening floods expected to occur at least once in the next 10 years. |
| GLACIAL LAKE OUTBUST FLOOD | Glacial Lake Outburst Floods, driven by climate change and rapid glacier retreat, pose threats from 17 potentially dangerous glacial lakes. Bhutan has experienced 17 GLOF events since the 19th century, with significant damage to Punakha Dzong in 1957 and 21 fatalities in the 1994 event. In June 2015, heavy rainfall triggered a GLOF with a discharge of 1198 $m^3/s$ at Punatsangchu hydropower project site. |
| WINDSTORM | Windstorms frequently damage rural homes and crops, with a severe event in April 2022 affecting nine dzongkhags and resulting in the loss of over 150 acres of maize field and damages to 989 structures, including homes and public infrastructure. |
| EARTHQUAKE | Earthquakes, due to Bhutan's seismically active location, have resulted in 18 significant events over the past 120 years, with an average magnitude of 6.3 on the Richter scale. The 2011 earthquake, measuring 6.9, caused one fatality, 14 injuries, and substantial economic losses. |
| LANDSLIDE | Landslides, often triggered by heavy rainfall, cause major disruptions and have become life-threatening, as seen in June 2021 when 10 people in Gasa were buried. Landslide susceptibility is classified as high according to ThinkHazard!, GFDRR. This means that the country has rainfall patterns, terrain slope, geology, soil, land cover and (potentially) earthquakes that make localized landslides a frequent hazard. |

| | |
|---|---|
| **DROUGHT** | With a changing climate, Bhutan is expected to experience two types of droughts, namely meteorological (usually associated with a precipitation deficit) and hydrological (usually associated with a deficit in surface and subsurface water flow, potentially originating in the region's wider river basins). The country is already experiencing prolonged and extreme droughts in various regions affecting water availability for agricultural purposes. Most dzongkhags have reported drying of water sources in their localities. |
| **FOREST FIRE AND STRUCTURAL FIRE** | Fires, both structural and forest, pose significant threats to lives and assets, with traditional structures particularly vulnerable due to their wooden construction. Notable incidents include the 2012 destruction of the 375-year-old Wangdiphodrang Dzong and the loss of Drukgyel Dzong in 1951. Between 1992 and 2022, 1,656 wildfire incidents affected over 172,974 acres of forest, with a high probability of significant wildfires occurring annually. These hazards collectively undermine economic development and social stability in Bhutan. |
| **EPIDEMICS (COMMUNICABLE, ZOONOTIC DISEASES, FOOD SAFETY)** | Biological hazards significantly increase disaster risk by exposing populations to vector-borne diseases such as bird flu, avian influenza, and COVID-19. |
| **PLANT AND ANIMAL DISEASE EPIDEMICS** | In Bhutan, zoonotic diseases like rabies and Highly Pathogenic Avian Influenza are prominent, with outbreaks affecting both humans and livestock, which are integral to the country's farming system. Bhutan's diverse agro-ecological regions and traditional farming practices also make it vulnerable to pests and diseases that threaten major crop productivity. |
| **CYBER SECURITY** | The growing number of cyber threats poses a substantial risk to both citizens and the government's digital assets. The Royal Audit Authority's (RAA) 2023 "Performance Audit Report on Preparedness for Cybersecurity" highlights a worrying increase in cyber incidents reported by government agencies, ranging from phishing attempts to data breaches. This is especially critical as the National Digital Identity system, which will store vast amounts of sensitive personal data, becomes more widely implemented. |

# B. Economic Impact and Linkages

**The stress test analysis established the relationship between infrastructure services or functions and key sectors of the economy, to better understand the importance of the resilience of these services.** Table 4 gives an overview of Bhutan's economy, identifies ten key industries in the country and highlights the dependencies of economic sectors on the critical functions. These economic activities require infrastructure systems to function. For example, both 'transport of passenger and cargo' as well as 'build and maintain road infrastructure' (roads and bridges) are critical for agriculture, manufacturing, construction, hotels and restaurants, etc. By understanding Bhutan's economic structure, including its supply chains, we analyse how disruptions to critical infrastructure propagate through the economy. For Bhutan, the road transport system, water supply systems, and electricity transmission and distribution systems need to be prioritized from the perspective of economic impacts. This is typically done through a deep dive into each sector and related functions.

*Table 4. Infrastructure functions and economic linkages*

*Note: Scores range from 0 to 5, with '0' representing a very weak relationship and '5' representing a very strong relationship*

| CRITICAL INFRASTRUCTURE FUNCTIONS | Agriculture | Manufacturing | Construction | Wholesale / Retail | Hotels & Restaurants | infocom | Finance & Insurance | Real Estate | Public Administration | Education | Score (from 0 to 1) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Supply water, treat and distribute | 5 | 3 | 3 | 2 | 4 | 2 | 2 | 2 | 2 | 3 | 0.59 |
| Manage wastewater | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 0.44 |
| Transport cargo and passengers by air | 2 | 2 | 2 | 2 | 3 | 2 | 1 | 2 | 2 | 2 | 0.40 |
| Transport cargo and passengers by road | 4 | 5 | 5 | 4 | 4 | 3 | 2 | 3 | 3 | 3 | 0.75 |
| Build and maintain bridges and tunnels | 4 | 5 | 5 | 4 | 4 | 3 | 2 | 3 | 3 | 3 | 0.75 |
| Generate electricity | 1 | 4 | 3 | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 0.48 |
| Transmit electricity | 2 | 4 | 4 | 2 | 4 | 4 | 4 | 2 | 4 | 2 | 0.64 |
| Provide internet routing, access and connection | 2 | 3 | 2 | 1 | 2 | 5 | 5 | 1 | 4 | 3 | 0.54 |
| Build and maintain schools facilities | 3 | 2 | 3 | 1 | 3 | 3 | 3 | 1 | 3 | 5 | 0.54 |
| Build and maintain health care facilities | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 0.39 |

# C. Stress Test Exercise

**Once the infrastructure functions, economic sectors, and hazards have been defined, the core of the stress testing consists of scoring the links** between them to identify key vulnerabilities and economic impacts. This requires considering:

- The level of dependency of each economic industry to each critical infrastructure functions
- The level of impact the selected hazards would have on the critical infrastructure functions
- The level of interdependencies between critical functions, or in other words, the cascading impact if a function fails

**The results of the stress testing exercise conducted in Bhutan are presented in Annex IV: Stress test results,** and used throughout the report to provide insights and evidence for designing appropriate recommendations.

# Principles for Resilient Infrastructure

**The fourth component of the approach is to use the Principles for Resilient Infrastructure to examine and assess the resilience of the country's infrastructure systems.** These principles, developed in collaboration with some 100 governments and international experts, form an international reference and the basis for identifying gaps and recommendations set out in this national resilient infrastructure plan.

Policymakers can adopt these principles at different stages of the infrastructure lifecycle. In general, the stages of the lifecycle are as follows: before construction (strategic planning and project prioritisation), during delivery (design, procurement and construction), during operation (operation and maintenance), and end of life. The National Plan considers these different stages to select the most impactful interventions.

**To define the actions in the National Plan, the rest of the report examines whether resilient practices, as defined in the principles, are already in place in the country and which ones should be improved based on the risks faced by the country and local circumstances.** To do this, an assessment of national policies and legislation was carried out using the principles along with a workshop with key stakeholders using a scorecard to assess their current infrastructure practices. Annex III: Principles of Resilient Infrastructure Review of Policies and Integration of the Principles for Resilient Infrastructure contains detailed results of this analysis. The main findings for each of the principles are presented below.

### PRINCIPLE 1 (CONTINUOUSLY LEARNING)

This principle aims to develop and update understanding and insight into infrastructure resilience. The table below illustrates how this principle can be implemented.

*Table 5. Lifecycle stage and examples of interventions regarding Principle 1.*

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| PLANNING | Set-up a system to ensure the dissemination of lessons learnt from past disasters to inform future planning (P1.3). |
| DELIVERY / CONSTRUCTION | Review and validate the climate and disaster scenarios used for infrastructure project preparation and design (P1.1). |

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| OPERATION AND MAINTENANCE | Enhance monitoring, sensing and early-warning systems to minimize outages of critical services (P1.2.).<br>Require operators to carry out regular stress tests to identify vulnerabilities and options for improvement (P1.4). |

Policy and institutional frameworks for disasters are well established, with the DM Act and the National Disaster Management Authority placing importance on DRR across sectors, including risk assessments, monitoring and early warning systems. However, implementation of the Act and related strategies face challenges due to capacity gaps, which hinder effective monitoring, stress testing, and the establishment of learning systems to inform future planning.

### PRINCIPLE 2 (PROACTIVELY PROTECTED)

This principle aims to determine and increase the level of hazard/threat preparedness and response. The table below illustrates how this principle can be implemented.

*Table 6. Lifecycle stage and examples of interventions regarding Principle 2.*

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| PLANNING | Develop a pipeline of safety-improvement interventions (P2.1).<br>Identify critical components of national infrastructure systems and prioritize them for necessary upgrades (P2.2).<br>Establish cross-sectoral planning committees to ensure all infrastructure sectors coordinate efforts and share data about cascading risks (P2.3). |
| DELIVERY / CONSTRUCTION | Require infrastructure design to include safe-to-fail solutions (e.g., plan for back-up energy-supply solutions and design for hazardous substances controls) (P2.5).<br>Require resilience assessments and interdependency analysis in infrastructure projects (P2.3)<br>Require the development of long-term maintenance plans as part of the initial approval process for infrastructure projects (P2.7).<br>Ensure that project appraisal takes a long-term approach and considers lifecycle costs, including those related to potential disasters (P2.8). |
| OPERATION AND MAINTENANCE | Build the capacity of local infrastructure operators to deal with disruptions (e.g., drills) (P2.4).<br>Ensure that critical services can be delivered through a diversity of scales: national, regional and local and operationalize redundancy for smaller-scale solutions (P2.6).<br>Establish dedicated funds specifically for ensuring proper maintenance (P2.7). |

Preparedness and response in Bhutan vary across critical sectors. For example, the energy sector implements proactive safety measures throughout the generation, transmission, and distribution phases, supported by long-term maintenance plans, capacity-building initiatives, and SOPs across the spectrum. However, there is a need for a deeper understanding of infrastructure interdependencies and network connections which calls for multi-sector coordination.

Various sectors have existing safety standards and regulatory frameworks, such as ERA for electricity and NEC for infrastructure and water quality, which help maintain service continuity during disruptions.

While some redundancy measures and emergency plans exist, like the Health Emergency and Contingency Plan and the Water Act prioritizing water for drinking and sanitation, challenges remain. These include limited budgets for long-term infrastructure investments and raising safety standards, especially in water, health, transport, and education sectors.

### PRINCIPLE 3 (ENVIRONMENTALLY INTEGRATED)

This principle aims to work in a positively integrated way with the natural environment. The table below illustrates how this principle can be implemented.

*Table 7. Lifecycle stage and examples of interventions regarding Principle 3.*

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| PLANNING | Promote the use of environmental information in infrastructure planning (P3.3). |
| DELIVERY / CONSTRUCTION | Conduct audits to control the environmental impacts of infrastructure systems (P3.1).<br>Include in project preparation documents an evaluation of the cost benefits of environmental solutions in comparison to other conventional or grey alternatives (P3.2).<br>Identify local resources and encourage their use for infrastructure projects through selection criteria in procurement (P3.5). |
| OPERATION AND MAINTENANCE | Lay down policies and regulations so that contractors and operators maintain the surrounding natural environment to reduce the threat of disruptions to critical services (P3.4). |

The application of Bhutan's environmental regulations under the aegis of the National Environment Protection Act 2007 is relatively uniform and effective across sectors, and closely monitored for high-risk investment infrastructure projects. There is a need, however, to enhance monitoring of emerging risks such as the handling and disposal of telecommunication fibres to prevent environmental and health risks.

### PRINCIPLE 4 (SOCIALLY ENGAGED)

This principle aims to develop active engagement, involvement and participation across all levels of society. The table below illustrates how this principle can be implemented.

*Table 8. Lifecycle stage and examples of interventions regarding Principle 4.*

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| PLANNING | Define guidelines for providing clear emergency messages (e.g., select the lowest literacy level for emergency messages that are compatible with the literacy level of the population) (P4.1). |
| DELIVERY / CONSTRUCTION | Ensure contractors and operators incorporate appropriate channels for emergency communications in the project design (P4.1). |

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| OPERATION AND MAINTENANCE | Define obligations for infrastructure sectors to adopt incentive policies or strategies for demand reduction, demand shifting, or demand avoidance (P4.3).<br>Promote education about resiliency, taking advantage of formal education programmes and local media, depending on the target audience (P4.2) .<br>Encourage operators to develop community participation programmes (P4.4). |

The level of engagement of communities has increased over the years in terms of overall disaster and climate risk education and awareness. However, there is room for each sector and cross-sector to promote infrastructure resilience literacy through both formal and informal education channels. For example, homeowners are not encouraged to insulate their homes, a practice that could reduce electricity demand for heating during lean seasons, when Bhutan is forced to import electricity from private energy companies at higher costs.

### PRINCIPLE 5 (SHARED RESPONSIBILITY)

This principle aims to share information and expertise for coordinated benefits. The table below illustrates how this principle can be implemented.

*Table 9. Lifecycle stage and examples of interventions regarding Principle 5.*

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| PLANNING | Engage with stakeholders and experts to select or devise information-sharing standards and incorporate them into regulation and law (P5.1).<br>Work with stakeholders and experts to encourage multi- and trans-sectoral collaboration for better infrastructure resilience (P5.2).<br>Develop and formalize data-security regulations for infrastructure resilience (P5.5). |
| DELIVERY / CONSTRUCTION | Collect construction and operational data formatted in compliance with relevant standards (P5.1). |
| OPERATION AND MAINTENANCE | Creates and utilizes data-sharing platforms with sufficiently robust communication channels to disseminate information to relevant stakeholders effectively (P5.4).<br>Collate and share data rapidly during disruptions to enable a coordinated response (P5.4). |

Risk assessments and related data and information are fragmented across sectors. There are efforts to consolidate and establish a single platform such as the multi-hazard disaster decision support system that requires the coordination of all related sectors. However, this will require capacity building in data infrastructure, interoperability, and usability for the governing agency as well as the users of the platform and its outputs.

### PRINCIPLE 6 (ADAPTIVELY TRANSFORMING)

This principle aims to adapt and transform to changing needs. The table below illustrates how this principle can be implemented.

*Table 10. Lifecycle stage and examples of interventions regarding Principle 6.*

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| PLANNING | Monitor demand and ensure that capacity can meet expected future demand either through demand reduction or increasing capacity (P6.4). |
| DELIVERY / CONSTRUCTION | Design systems according to local resources and capacity (P6.1).<br>Provide designs that allow usage to be measured and enable future changes to capacity (P6.2). |
| OPERATION AND MAINTENANCE | Monitor compliance with override capacity requirements allowing for human discretion, and report on non-compliance (P6.5). |

The adaptive capacity across the critical infrastructure sectors requires attention, especially in terms of sharing risk and return information and developing flexible management. This will further require data on service demand and usage to enable future planning. For example, the Department of Human Settlement faces issues with utility agencies failing to comply with planned common duct systems, leading to haphazard disruptions in services such as sewage, water, and cable networks.

In recommending interventions, the remainder of the report will consider whether resilient practices, as defined in the principles, are already in place in the country, and which ones should be recommended based on the country's risk landscape and local circumstances.

# Recommendations and Implementation Plan

The final component involves formulating a set of recommendations and an implementation plan based on the analysis outlined above. The recommendations are a result of the process of engaging 21 agencies across seven ministries, with input from key infrastructure stakeholders in Bhutan and support from international experts. Through this collaborative effort, both cross-sectoral and sector-specific recommendations were developed, culminating in a comprehensive National Plan for infrastructure resilience. The plan and respective recommendations were validated through stakeholder workshops and consultations to ensure broad support and alignment with national priorities. These recommendations are designed to support Bhutan's 13th Five Year Plan and will guide various sectors in developing their individual action plans.

The next section analyses cross-sectoral policies that have an impact on the resilience of infrastructure systems, while exploring the interdependence of different sectors. The final section provides a more in-depth analysis of each of the infrastructure sectors in order to formulate tailored recommendations.

# PART II. CROSS-SECTOR ANALYSIS

# Institutional Arrangement for DRR

To strengthen governance mechanisms for enhancing infrastructure resilience, it is essential to first understand the decision-making processes and responsibilities surrounding infrastructure management. The institutional framework for disaster risk reduction in Bhutan ensures coordinated and sustainable responses to the increasing risks, establishes clear roles and responsibilities across sectors, facilitates resource mobilisation, and enables integrated planning and policy implementation. It also enhances collaboration across sectors, including the private sector, academia and communities in an effort to reduce vulnerabilities and safeguard communities, infrastructure, and economies from disasters. Additionally, it fosters accountability and transparency in decision-making, to contribute to long-term resilience outcomes.

### THE NATIONAL DISASTER MANAGEMENT AUTHORITY (NDMA)

The NDMA chaired by the ex-officio Prime Minister with representation from key agencies is the highest decision-making body on DRR and disaster management in Bhutan. The NDMA is mandated to approve national disaster management policies, frameworks, contingency plans, hazard and vulnerability maps, standards and guidelines, mobilisation of funds, mainstreaming disaster risk reduction in development plans, policies, programmes, and projects, and to establish an Inter-Ministerial Task Force (IMTF).

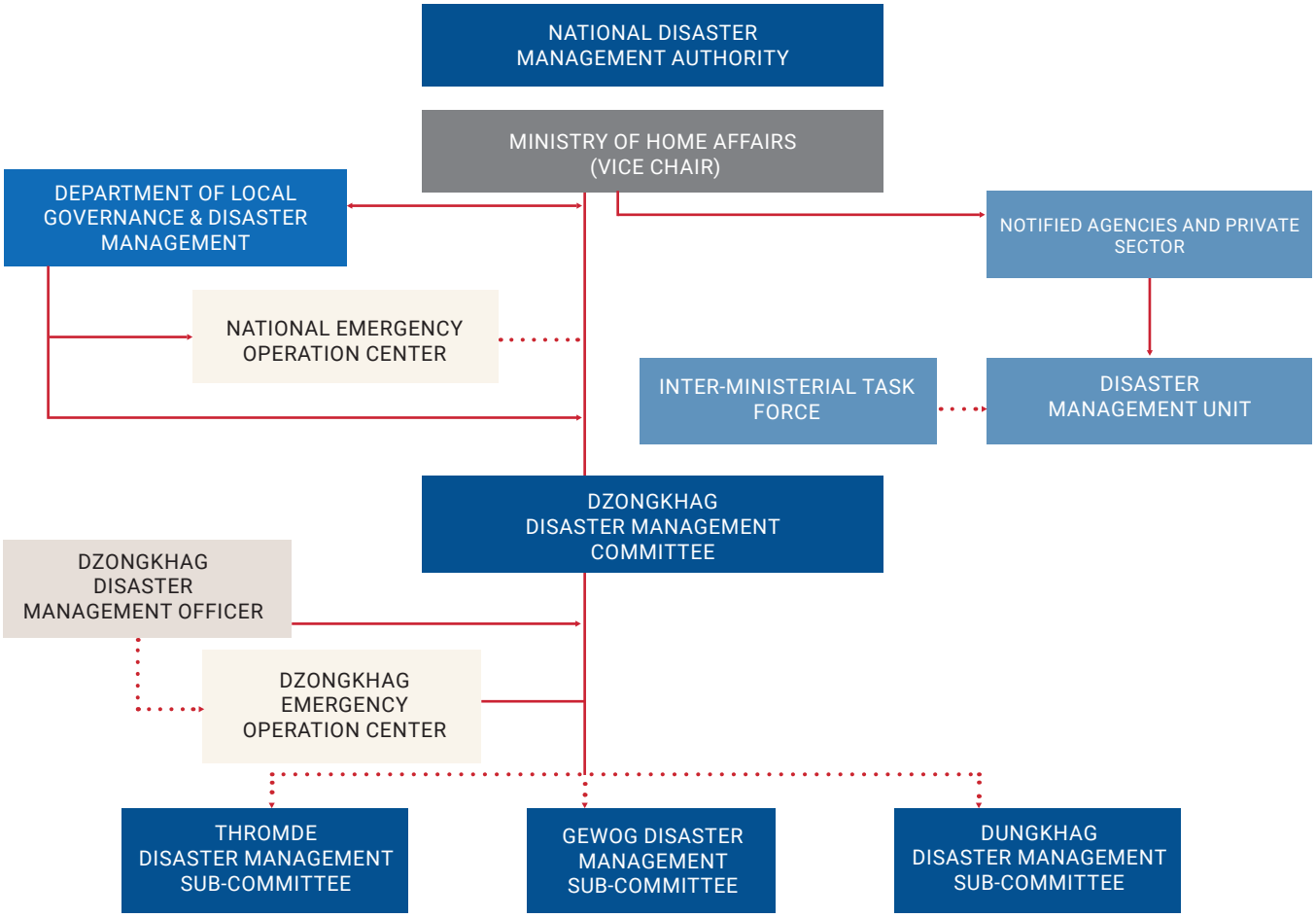
### THE INTER-MINISTERIAL TASK FORCE (IMTF)

The IMTF with technical experts from relevant and key agencies provides technical assistance in reviewing national disaster management plans and establishes critical disaster management facilities including the interim National Emergency Operation Centre (NEOC).

### THE DEPARTMENT OF LOCAL GOVERNANCE AND DISASTER MANAGEMENT (DLGDM)

The DLGDM is the designated secretariat and executive arm of the NDMA and the national coordinating agency for formulating disaster management policies, guidelines, roadmaps, and strategies; mainstreaming DRR; preparing and ensuring implementation of disaster management and contingency plans; ensuring effective institutional and critical infrastructure set up at the national and local levels; and building regional or international partnerships for disaster-related assistance.

*Figure 2. Institutional arrangement for DRR*




## SECTORAL DM UNITS

At the sector level, agencies including private entities are notified by the NDMA to institute disaster management units and prepare sectoral DM plans.

## DZONGKHAG/THROMDE DMC

All dzongkhags and thromdes are mandated to institute Dzongkhag/Thromde Disaster Management Committees and draft disaster management and contingency plans. The dungkhags and gewogs may be asked to draft their DMCP if required by the dzongkhag.

# Policy Framework for DRR and CCA

**The policy and regulations for DRR within sectors, as well as cross-cutting themes, directly determine the quality of assets and services, the effectiveness of public spending, and the incorporation of resilience measures.** This assessment process reviews the relevant policies and regulations which can influence the resilience of infrastructure systems in a country, as well as their key DRR components. A number of key policy documents were reviewed to assess their relevance for DRR and identify potential gaps.

*Table 11. Integration of DRR and CCA in key policies*

| TYPE | KEY POLICY DOCUMENT | KEY FEATURES OF DRR AND CCA INTEGRATION |
|---|---|---|
| INTER-SECTORAL REGULATORY MECHANISMS | DISASTER MANAGEMENT ACT OF 2013 | Establishes key institutions and mechanisms for risk reduction and disaster management, including the National Disaster Management Authority. It mandates the mainstreaming of DRR into plans, policies and programmes at all levels, creation of a disaster management activities fund, NEOC, and Early Warning Systems, ensuring alignment with multi-hazard risk assessments and sector safety requirements. The current act is silent on climate change risks and adaptation provisions. It is currently being updated and is expected to sufficiently address climate-related disaster risk reduction in plans and policies. |
| | DRM STRATEGY 2017 | Engages relevant sectors to prioritize risk assessments, early warnings, risk governance, preparedness, and response with a "build back better" approach. Identifies investment gaps, and resource allocation needs, and prioritizes non-structural measures and risk transfer modalities. |
| | CLIMATE CHANGE POLICY 2020 | Provides guidance and tools for climate adaptation and mitigation measures, including opportunities for synergies and cross-cutting issues, such as disaster risk reduction. |
| | NATIONAL ADAPTATION PLAN OF THE KINGDOM OF BHUTAN 2023 | The plan has a focus on resilient infrastructure across sectors to address climate change. It includes seven thematic areas and strategic interventions, which will be reviewed and updated every five years. It prioritizes water, agriculture, biodiversity, climate services, and disaster risk reduction. |

| TYPE | KEY POLICY DOCUMENT | KEY FEATURES OF DRR AND CCA INTEGRATION |
|---|---|---|
| NATIONAL PLANS AND DRR PRINCIPLES INTEGRATION | FIVE YEAR PLANS | The 11th Five Year Plan (2013-2018) began integrating DRR and CCA with dedicated key performance indicators, and the 12th Plan (2018-2023) continued this initiative. The 13th Plan (covering 2024-2029), aligned with CNDP 2030 and SDGs, aims for a sustainable environment and disaster/climate resilience. |
| | COMPREHENSIVE NATIONAL DEVELOPMENT PLAN 2030 | The plan outlines strategies across 14 priority sectors. Although DRR and CCA are not direct criteria for prioritization, targets in some sectors include security and disaster risk analyses. It promotes innovative technology for mitigating disasters and ensuring balanced economic and environmental growth. |
| | NATIONAL LAND USE PLAN | The NLUP is based on five principles, two of which focus on DRR: (i) assessing the environmental, disaster prevention, and economic effects of land use; (ii) using GIS data updates for scientific land use reviews. |
| FINANCING MECHANISMS FOR DRR/ INVESTMENT MANAGEMENT FOR DRR | PUBLIC FINANCE ACT | The act provides three risk retention instruments: (i) response and relief expenditure; (ii) immediate restoration financing for essential public infrastructure; (iii) funding recovery/reconstruction via annual planning. A disaster risk financing strategy is needed to address funding gaps for DRM programmes. |
| | DISCLOSURE OF RISK-RELATED DATA | The Corporate Regulatory Authority enforces auditing and governance codes, and the Public Finance Act requires state-owned enterprises to submit annual reports with audited statements. However, there are no regulatory mandates to disclose environmental and risk assessments. |

# Cross-Sectoral Interdependencies and Cascading Risks

**Analysing infrastructure resilience requires a thorough understanding of the interdependencies among critical infrastructure functions, as these functions are closely interconnected.** The stress test assessed each critical infrastructure function in detail, highlighting the interdependencies among these functions and assessing the degree of dependence—high, medium, or low. For instance, a disruption in one sector, such as a power outage, has a high impact on other essential services like communication systems, transportation, water and health systems. On the other hand, the power supply itself has a moderate dependency on transportation, communication systems, and water sector operations. By examining these interconnections, agencies and decision-makers can better understand the impact of cascading failures and identify interventions for ensuring the continuity of vital services.

**Once these interdependencies were identified, stakeholders discussed the risks stemming from the cascading failures of these interconnected systems.** By simulating various stress scenarios, the tool assessed the potential impact on different infrastructure sectors, helping to pinpoint vulnerabilities and analyse possible domino effects. This analysis is crucial for developing effective prevention and mitigation strategies for planners and decision-makers while facilitating collaboration across sectors.

**While sector-related interdependencies and understanding of cascading risks are featured in the respective sections, several key findings emerged that require cross-sector and multi-sector interventions.** Strengthening governance and coordination mechanisms for overseeing infrastructure resilience is critical. This includes defining and identifying critical infrastructure sectors specific to Bhutan and establishing a dedicated technical task force for disaster risk reduction and resilience. Codes and regulations that cut across infrastructure sectors need updating to include climate and disaster resilience. Technical capacity building of agencies that serve multi-sector planning and decisions such as GIS, mapping, remote sensing, surveying, and resilience design and planning were identified. Additionally, creating a national database to track critical infrastructure systems and performance, along with sharing data, reports, and findings is essential for decision-making and enhancing resilience across sectors.

# Cross-sector Gaps and Implementation Plan

*Table 12 Cross-sector Implementation Plan*

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| Although the DM Act requires mainstreaming of DRR into sector plans and policies, integration activities remain insufficient and often occur in silos. This has resulted in duplication of efforts, inefficient resource use, and fragmented implementation across national and local development plans. | **Improve mainstreaming Disaster Risk Reduction and Climate Change Adaptation across sectors.**<br><br>Type:<br>Policy and Regulation | • Standardize the processes across all sectors.<br>• Raise awareness across all levels of officials/ sectors/ stakeholders.<br>• Draft comprehensive mainstreaming guidelines for DRR and CCA.<br>• Include DRR and CCA performance indicators and monitoring plans in sectoral annual plans. | **Continuously Learning** | **Medium**<br><br>Timeframe: Short Term – Within 3 months | **Lead: DLGDM**<br><br>Support: Relevant agencies |

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| There are inadequate multi-hazard risk assessments across sectors and an absence of stress testing for critical infrastructure.<br><br>e.g. existing building regulations, codes and land-use plans do not fully incorporate provisions for multi-hazard assessments nor update climate and disaster risk zoning periodically based on new and reliable data. | **Strengthen the resilience of critical infrastructure by integrating multi-hazard risk assessments, regular stress testing, and updated climate and disaster risk zoning into national regulations, ensuring sectors adopt standardized guidelines for evaluating and enhancing infrastructure resilience.**<br><br>Type:<br>Policy and Regulation | • Review DM regulations to include critical infrastructure governance.<br><br>• Draft sector-specific multi-criteria risk assessment and environmental audits. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Medium term | **Lead:**<br>**DLGDM**<br><br>Support:<br>Relevant sectors |
| | | • Draft guidelines for conducting stress tests with criteria or scores for evaluating the resilience of roads under various stressors such as heavy traffic, extreme weather events, and other natural hazards. | **Continuously Learning** | **High**<br><br>Timeframe:<br>Short Term | **Lead:**<br>**LG, DOID, DOST**<br><br>Support:<br>All stakeholders |
| | | • Carry out annual stress tests on ICT assets and systems based on sector stress testing guidelines. | | **High**<br><br>Timeframe:<br>Short Term | **Lead:**<br>**GovTech Agency**<br><br>Support:<br>BICMA, ISP & TSP, BPC ICT firms, DLGDM, DoW, DECC, NLC |
| | | • Conduct annual water and wastewater infrastructure and service stress tests against existing standards, regulations and guidelines - assessment of the resilience of infrastructure and operations. | | **Medium**<br><br>Timeframe:<br>Short Term | **Lead:**<br>**DOID**<br><br>Support: DOW |
| There are inadequate multi-hazard risk assessments across sectors and an absence of stress testing for critical infrastructure.<br>E.g. existing building regulations, codes and land-use plans do not fully incorporate provisions for multi-hazard assessments, nor update climate and disaster risk zoning periodically based on new and reliable data. | **Building codes and land-use plans need to be reviewed and updated requiring comprehensive multi-hazard assessments that consider a wide range of potential risks to integrate emerging risks based on assessments.**<br><br>Type:<br>Policy and Regulation | • Update building codes to include multi-hazard risk assessment.<br><br>• Update Bhutan Building Regulations to include multi-hazard risk assessment.<br><br>• Update land use plans to include multi-hazard risk assessment. | **Continuously Learing** | **Medium**<br><br>Timeframe:<br>Short Term<br>2024 - 2025 | **Lead:**<br>**DHS, MoIT**<br><br>Support:<br>Relevant sectors |
| | **Integrate Climate Smart Land Use Planning components in Spatial Plans and standards.**<br><br>Type:<br>Policy and Regulation | • Draft/update spatial planning guidelines to include Climate Smart Land Use Plan.<br><br>• Update existing spatial plans. | | **Medium**<br><br>Timeframe:<br>Continuos Process | **Lead:**<br>**DHS, MoIT**<br><br>Support:<br>Relevant sectors |
| | | • Review Spatial Planning Standards to incorporate resilient infrastructure planning component. | | **Medium**<br><br>Time frame:<br>Short term<br>2025 -2026 | **Lead:**<br>**DHS, MoIT**<br><br>Support:<br>Relevant sectors |

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| There is a lack of a dedicated disaster risk reduction financing strategy creating significant investment gaps in DRR for critical infrastructure investments. Meanwhile, public-owned infrastructures are generally uninsured, exposing critical assets to higher financial risks. | **Establish DRR financing strategy to reduce risks and enhance protection for critical infrastructure.**<br><br>Type:<br>Policy and regulation | • Formulate a DRR financing strategy focusing on resilient infrastructure.<br><br>• Explore risk transfer mechanisms (e.g. parametric insurance). | **Adaptively Transforming** | **Medium**<br><br>Timeframe:<br>Short term | **Lead:**<br>**MoF and DLGDM**<br><br>Support:<br>Relevant sectors |
| There is a lack of dedicated governance and coordination mechanisms focused on overseeing the resilience of critical infrastructure. | **Enhance critical infrastructure resilience governance through coordinated mechanisms and commitments.**<br><br>Type:<br>Governance and Coordination | • Identify and define critical infrastructure sectors in the context of Bhutan.<br><br>• Establish a task force for critical infrastructure DRR and resilience engaging technical resources from relevant sectors. | **Continuosly Learning** | **High**<br><br>Timeframe:<br>Short term | **Lead:**<br>**DLGDM**<br><br>Support:<br>All stakeholders |
| There is a lack of coordination among utility agencies regarding the use of planned common ducts as outlined in the land use plan for utility services. This misalignment in work plans, driven mainly by budget constraints of the local government, adversely affects service quality and aesthetics. | **Establish a coordinating framework with all utility agencies (local governments) to develop integrated, sustainable master plans for common utilities in the four Thromdes and other planned areas.**<br><br>Type:<br>Governance and Coordination | • Carry out consultation meetings with all utility agencies to coordinate work plans and budgeting.<br><br>• Develop PPP model for utility services. | **Shared Responsibility** | **Medium**<br><br>Timeframe:<br>Long Term | **Lead:**<br>**DHS, MoIT**<br><br>Suport:<br>Relevant sectors |
| There is a lack of technical capacity across sectors to conduct comprehensive hazard and risk assessments, including seismic, landslide susceptibility, and hazard mapping, as well as the use of advanced techniques such as remote sensing and GIS for monitoring critical vulnerabilities. | **Enhance capacities in surveying, GIS mapping, geodatabase development, climate Smart LUP, resilient infrastructure planning, design, and construction, and disaster management.**<br><br>Type:<br>Capacity Building | • Conduct training on comprehensive hazard and risk assessments, surveys, GIS mapping, Smart LUP, resilient infrastructure planning and design. | **Adaptively Transforming** | **Medium**<br><br>Timeframe:<br>Short term | **Lead:**<br>**DHS, MoIT**<br><br>Support:<br>Relevant sectors |
| | **Build technical expertise/ capacity of DGM focusing on seismic and landslide assessment, mapping, GIS and remote sensing.**<br><br>Type:<br>Capacity Building | • Conduct training on the generation of micro seismic hazard and risk maps for DGM.<br><br>• Conduct training on landslide susceptibility and hazard maps using GIS and remote sensing techniques. | | **Medium**<br><br>Timeframe:<br>Short term<br>August 2024 - June 2025 | **Lead:**<br>**DGM, MoENR**<br><br>Support:<br>DLGDM, DHS, DID |
| | | • Short-term training on landslide assessment for DGM. | | **High**<br><br>Timeframe:<br>Short term<br>August 2024 - June 2025 | **Lead:**<br>**DGM, MoENR**<br><br>Support:<br>NLCS, DLDGM, UNOSAT |

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| NCHM has drafted a framework to share hydro-meteorological data for information collected by NCHM in geographical locations within Bhutan. However, there are limited provisions for open data and infrastructure-related information sharing across other sectors. | **Enhance data sharing across infrastructure sectors to improve cross-sectoral collaboration for infrastructure planning and decision-making.**<br><br>Type:<br>Governance and Coordination | • Review the existing policies / frameworks governing data sharing (e.g. GI Policy with NLCS).<br><br>• Draft data sharing guidelines/ framework that ensures trust, data security, as well as access to information/data for water and transport sectors. | **Shared Responsibility** | **Medium**<br><br>Timeframe:<br>Medium term | **Lead:**<br>**GovTech Agency**<br><br>Support:<br>Stakeholders |
| The capacity and platforms for data sharing between energy sectors and relevant organisations are inadequate, reducing the ability to respond to emerging vulnerabilities and hindering coordinated resilience efforts. | **Enhance real-time information exchange and data sharing between energy sectors and relevant organisations, enhancing the ability to respond to emerging vulnerabilities and fostering coordinated resilience efforts across the infrastructure sectors.**<br><br>Type:<br>Data Sharing Platform | • Develop and implement a centralized, interoperable data-sharing platform that facilitates real-time information exchange between sectors and relevant organisations, enabling timely responses to emerging vulnerabilities and promoting coordinated resilience efforts across the sector. | **Shared Responsibility** | **High**<br><br>Timeframe:<br>Medium term | **Lead:**<br>**BPC, DoE**<br><br>Support:<br>DGPC<br>Relevant stakeholders |

*Image by Vikramjit Kakati from Pixabay*

# PART III. SECTORAL RESILIENCE: RISK AND VULNERABILITY ASSESSMENT USING THE GLOBAL METHODOLOGY

**Part III of this National Infrastructure Plan delves into the risks and resilience of ten critical infrastructure functions across six main sectors in Bhutan, namely transport, energy, ICT, water, health and education.** While it does not cover the functions of the entire sector, the selected functions represent the areas most vital to its resilience. The analysis identifies key vulnerabilities and resilience gaps within these functions, offering insights into how they can be strengthened against climate and disaster risks. This section aims to guide targeted interventions and policy decisions that enhance the overall resilience of these sectors.

**As part of the Enhancing Infrastructure Resilience through Strengthened Governance project, a deep dive into the water sector was conducted.** This was particularly necessary after the stress tests and the application of the global methodology found that the water sector is highly vulnerable, but also critical to the country's economy and society. This highlights the need for similar in-depth assessments for other sectors and critical infrastructure functions that are identified as most vulnerable to disaster and climate risks.

# A. TRANSPORT SECTOR

## ROAD TRANSPORT

The road transport sector in Bhutan, comprising roads, bridges, and tunnels, is classified into five main categories: highways; district (dzongkhag) roads; urban (thromde) roads; farm roads; and access/ feeder roads. Access roads are built to connect hydro plants, schools, health facilities, and forestry land. As of 2020, Bhutan's road network has a total road length of roughly 18,000 kilometres, of which 61% are farm roads, around 15% are national highways, and about 11% are dzongkhag roads. By June 2022, around 122,865 vehicles were plying across these roads, facilitating both domestic and international passenger and cargo.

**For Bhutan, a landlocked, developing country, road transportation networks serve as the backbone of the country's economy delivering goods and services, promoting trade, and tourism, and contributing to economic development as well as enhancing social connectivity.** For example, trade accounts for 84% of the GDP, and nearly all trade relies on road transport. With urbanisation on the rise and projections indicating that 50% of the population will reside in urban areas by 2037[1], the demand for urban transport and inter-dzongkhag connectivity is expected to increase. Other development trends impacting the transport sector include hydropower development, industrial growth, tourism, energy transmission and distribution, and regional connectivity.

## AIR TRANSPORT

Bhutan has two international airports in Paro and Gelephu, two domestic airports in Bumthang and Yonphula, and two airlines: Drukair and Bhutan Airlines operating international and domestic flights. Bhutan has bilateral air services with seven countries including Bangladesh, India, Nepal, Thailand, Myanmar, Singapore, and Maldives.

**The air transport sector in Bhutan is a significant contributor to the nation's economy, primarily through its support of the tourism industry, which is a major economic driver.** This is critical given Bhutan's challenging terrain and limited alternative modes of transport. Connectivity is another critical area where air transport has a profound impact on the Bhutanese economy, bridging geographic barriers as a landlocked country and connecting remote regions with major economic hubs globally. For Bhutan, air transport service is also critical for emergency responses, particularly in a region

1. *National Statistical Bureau (2022), Population and Housing Census of Bhutan*

prone to natural hazards. Bhutan's 13th Five-Year Plan (FYP) underscores the growing importance of the aviation sector, focusing on infrastructure upgrades, adoption of advanced technologies, and revisions to civil aviation policies. The plan emphasizes robust safety measures, improved connectivity, and the development of a sustainable aviation industry in line with international standards. Bhutan's economy significantly benefits from tourism, which relies heavily on air transport. The availability and efficiency of air transport services directly impact tourist arrivals on one hand, and on the other, air transport provides an essential link both within the country and internationally, connecting Bhutan to the region and global economy.

# Transport Sector Institutions and Policy Framework

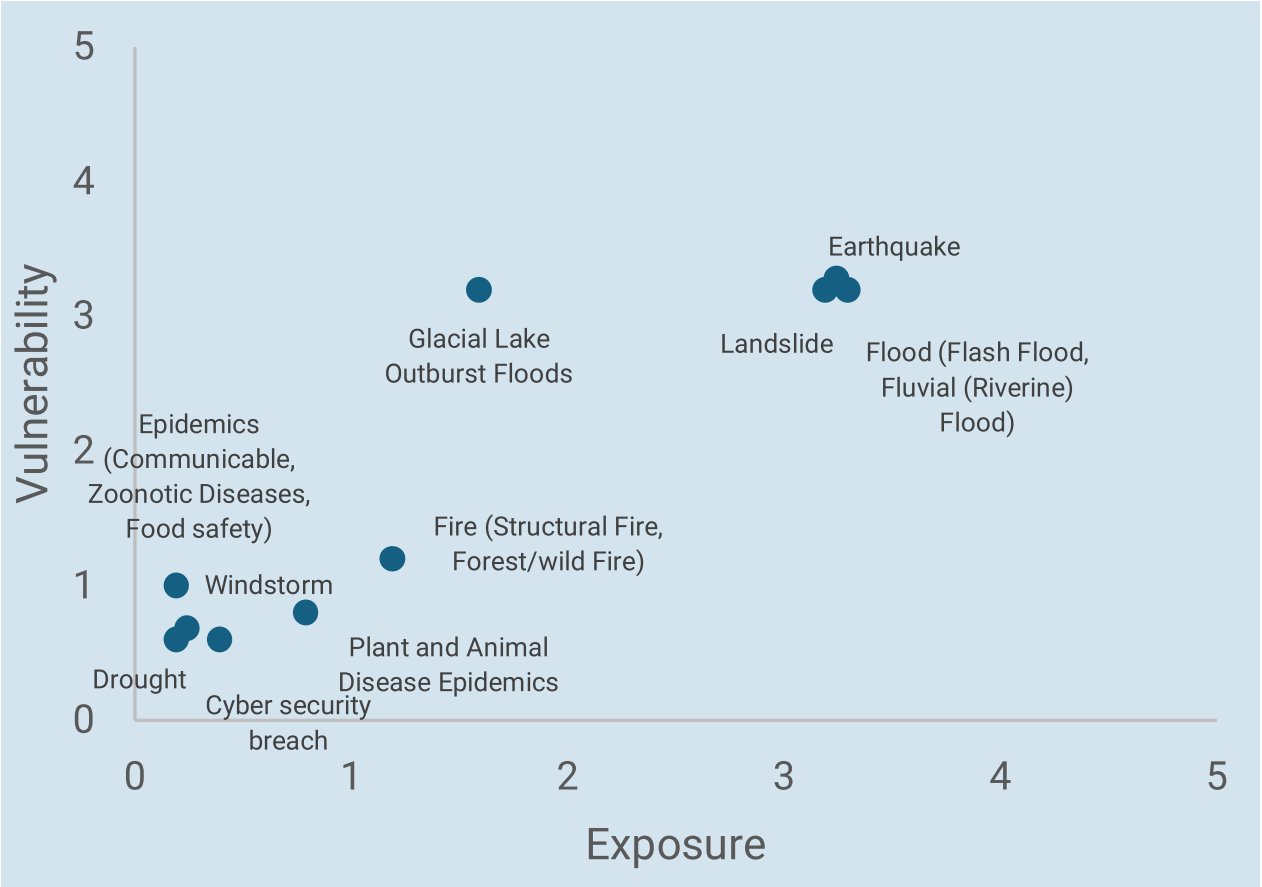
| TRANSPORT | |
|---|---|
| **POLICYMAKERS** | The Ministry of Infrastructure & Transport and its corresponding departments are the authoritative bodies responsible for setting, formulating and reviewing the vision, policy, and planning for each mode of transport in the country. It also manages intra-sectorial coordination for various aspects related to human settlement planning and development, surface and air transport, construction, infrastructure development, housing, and postal services. In addition, it prepares and reviews spatial plans and infrastructure master plans. |
| **REGULATORS** | The Bhutan Construction and Transport Authority is mandated to develop, review, and update rules and regulations related to safety and public services in the construction and surface transport sector. Its responsibilities include enforcing safety and professional standards, adopting guidelines and standard operating procedures, compliance monitoring of spatial plans, regulating and managing the safety of the public transportation system, improving service delivery and institutional coordination, conducting compliance auditing for safety and quality, proposing fees and charges, developing specifications and standards, and undertaking research and development in the construction and surface transport sector. |
| **OWNERS** | The Department of Surface Transport, MoIT (national highways), the Thromdes and Dzongkhags (local governments) own roads and bridges within the jurisdiction.<br>The Department of Air Transport owns the aviation infrastructures and assets such as airports, aerodromes/hangars, runways, terminals, air traffic control (ATC) systems etc.<br>The airline companies, Druk Air Corporation Ltd (SoE) and Bhutan Airlines, a private company, own the fleet of aircrafts and helicopter(s). |
| **OPERATORS** | DrukAir Corporation Ltd (SoE), Bhutan Airlines (private), Bhutan Postal Corporation, public transport service operators (private), the taxi association of Bhutan are the main operators. |

| | |
|---|---|
| **POLICY** | The Bhutan Civil Aviation Authority (BCAA) regulates the overall aviation sector in Bhutan, and the Department of Air Transport (DOAT) oversees the day-to-day operation. The Civil Aviation Act of 2016 establishes the regulatory framework for all civil aviation activities in the country aimed at promoting the development of civil aviation in Bhutan.<br>The Road Safety and Transport Act 1999 established the erstwhile Road Safety and Transport Authority (now Bhutan Construction and Transport Authority) to develop and implement road safety strategies and supervise regulations applicable to road traffic.<br>The Road Act of the Kingdom of Bhutan 2004 provides the legal framework for road management and maintenance, including provisions for updating infrastructure standards, protecting and maintaining roadways, with a strong emphasis on environmental considerations and user safety, and clearly delineating responsibilities among various government bodies and agencies. |

# Transport Sector Vulnerabilities

## TRANSPORT CARGO AND PASSENGERS BY ROAD

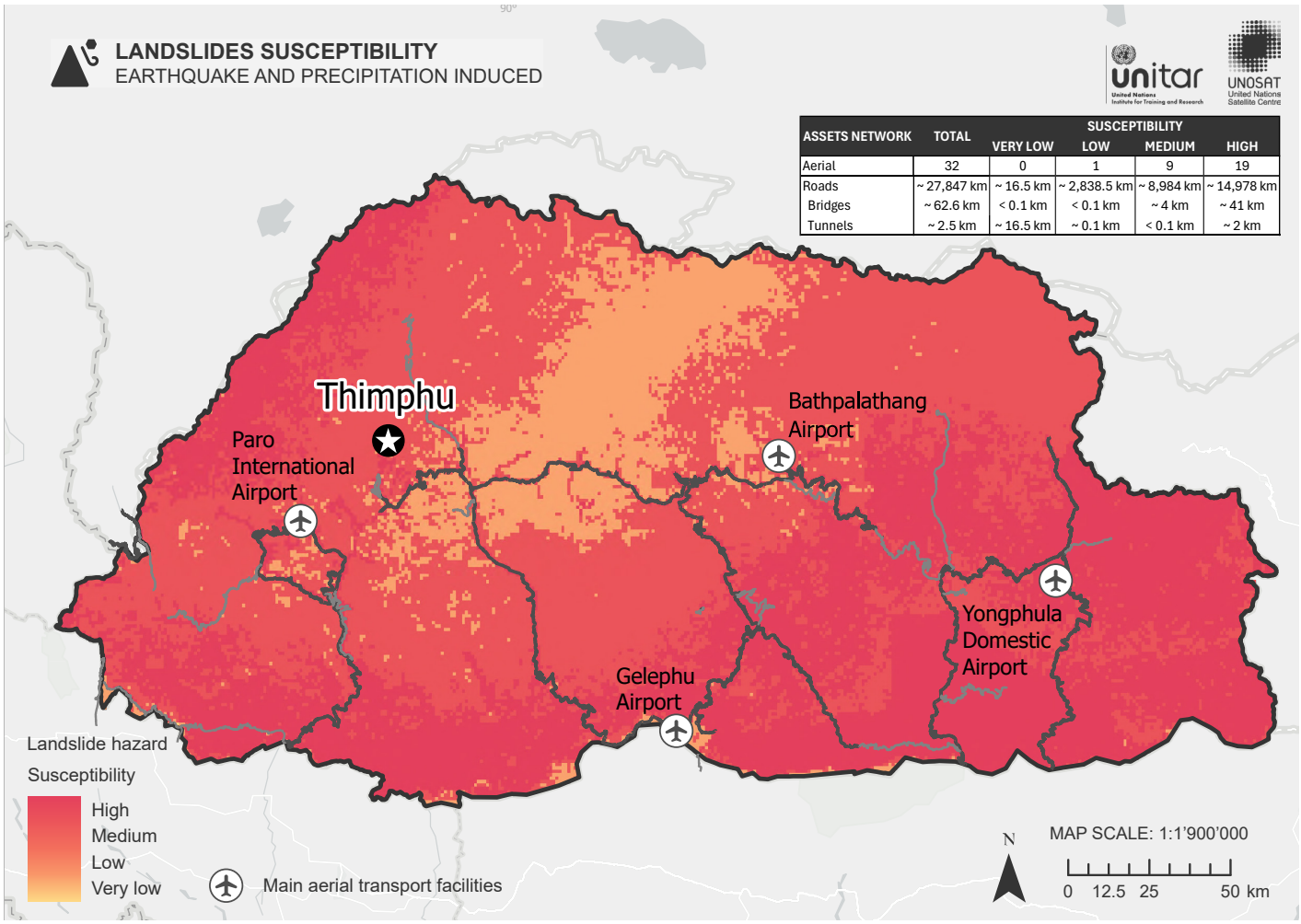
*Figure 3. Road transport risk matrix*



## ROAD TRANSPORT

Despite its crucial role in supporting Bhutan's economic and social sectors, the road transport infrastructure faces considerable challenges. The country's difficult geographic terrain, adverse weather conditions, and climate change impacts significantly hinder the construction, maintenance, and delivery of services, making these processes both complex and costly. The stress test identified landslides as the most significant threat to road and bridge infrastructures in Bhutan, often triggered by heavy monsoon precipitation and weak geological foundations leading to slope failures. Figure 4 provides the results from a quantitative analysis of asset exposure. The map depicts asset exposure to landslides based on a global model that combines landslide risks induced by earthquakes and precipitation. According to UNOSAT's analysis of transport asset exposure shown in Figure 4, 29 out of 32 transport assets are located in landslide-prone areas[2]. Specifically, Yongphula Domestic Airport and Paro International Airport are situated in highly susceptible areas, while Bathpalathang Airport is in an area with medium susceptibility, and Gelephu Airport is in a low susceptibility area. Additionally, approximately 14,978 kilometres of roads, around 41 kilometres of bridges, and just over 2 kilometres of tunnels are within highly susceptible zones. The stress test also identified earthquakes and floods as significant threats. Such disruptions isolate communities and create cascading effects that impact critical economic and social sectors. Consequently, annual investments in road infrastructure construction and recurrent maintenance are given high priority in the planning and budgeting processes.

*Figure 4. Transport sector assets exposed to landslides. Source: World Bank's GFDRR platform and DLGDM.*




2. Global landslide hazard map, https://datacatalog.worldbank.org/search/dataset/0037584/Global-landslide-hazard-map&quot

## AIR TRANSPORT

Despite the growing importance of air transport as an economic enabler, Bhutan still faces geographical constraints that limit the physical expansion and therefore the capacity of the infrastructure to handle both passengers and cargo critical for trade and tourism. Due to difficult terrain and weather conditions, air navigation and airport development and operations in the country present unique challenges. Aircraft operations are limited during the windy months and sometimes restricted, significantly reducing capacity for passenger and cargo movement. The domestic airports have similar challenges, with current facilities being basic and capable of supporting only limited flight operations and minimal passenger accommodation.

Earthquakes and windstorms emerge as the most significant threats. Floods, including flash floods and riverine floods, also present considerable risks to airport assets and related services along the river banks. Both Paro International Airport and the domestic airport in Bumthang are directly exposed to potential floods.

To better understand the vulnerabilities within the air transport system, the stress test analysis highlighted the interdependencies between cargo and passenger transport and other essential functions of the system. This interconnectedness reveals the sector's heightened vulnerability to disruptions in these supporting services and therefore cascading risks with significant consequences for the overall resilience of the air transport sector as highlighted in Table 14.

*Table 14. Air transport dependency on critical functions & rationale*

| HIGH | MEDIUM |
|---|---|
| **Generate & transmit electricity** *(heavily relies on electricity for various operational aspects, lighting of roads and tunnels, the operation of electric vehicles, & public transport communication)* | **Supply, treat and distribute water** |
| **Provide internet routing, access, and connection** *(Modern road transport systems depend on the Internet for a range of functions, such as GPS navigation, real-time traffic monitoring and communication and are essential for logistics and fleet management systems)* | **Manage wastewater** *(in the context of stormwater drainage systems, flood prevention for maintaining road integrity)* |

# Current Resilience Measure

## ROAD TRANSPORT

A comprehensive legal framework is in place for both road and surface transport, outlining the responsibilities of central and local government bodies in planning, implementing, and monitoring road networks. **There are guidelines on the design, construction and maintenance of road infrastructures incorporating climate-resilient features including surveys, geotechnical studies, and maintenance.**

The Bhutan Construction and Transport Authority ensures that construction and transportation activities comply with established standards, thereby contributing to the resilience and safety of the road network and surface transport.

The Road Sector Master Plan is complemented by the master plan study on road slope disaster management through the preparation of an inspection manual, slope disaster inspections and a database to advise on countermeasures.

Initiatives to improve engineering and construction technology and standards, minimize environmental impacts and ensure all-weather accessibility are integrated into the Integrated Strategic Vision for Surface Transport. The Road Asset Management System is a critical tool for enhancing resilience in the road sector and Standard Operating Procedures have been drafted for the restoration of road networks and ongoing operations and maintenance (O&M).

Furthermore, there is some capacity to conduct geohazard risk assessments along national highway corridors to manage road assets.

## AIR TRANSPORT

Institutional arrangements are established, namely the Department of Air Transport with the core mandate to develop and manage airport and air navigation infrastructure and services to international standards.

The Bhutan Civil Aviation Authority has the core mandate to regulate air transport services. The National Aviation Safety Plan provides strategic direction for national safety issues, sets national aviation safety goals and targets, and presents a series of Safety Enhancement Initiatives (SEIs) to address identified safety deficiencies and achieve national safety goals and targets.

There are initiatives such as the Air Transport Connectivity Enhancement Project to enhance the capacity and security of existing airports.

Disaster Management and Contingency Plans are required and drafted for mandated agencies to ensure the safety of staff, reduce loss of property, build awareness of risk reduction, and establish institutional arrangements for the continuity of air services.

The NCHM measures and provides weather condition services for air navigation.


*Photo Credit: Doug Knuth from Woodstock, IL; https://www.flickr.com/photos/dknuth/8202279871/*

# Gaps and Implementation Plan

*Table 15. Transport Implementation Plan*

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| Monitoring of farms, access roads, and related hazards is insufficient. | **Enhance the capacity of local governments to monitor dzongkhag/gewog/ access roads.**<br><br>Type:<br>Policy and Regulation, and Capacity Building | • Draft monitoring framework for farms and access roads, focusing on identifying and assessing hazards such as landslides, floods, etc. | **Continuously Learning** | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**DOID, DOST**<br><br>Support:<br>LG |
| | | • Conduct trainings for local government engineers, planners, and relevant stakeholders on the application of the guidelines and monitoring framework. | | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**DOID, DOST**<br><br>Support:<br>LG |
| The current spatial plans do not integrate a comprehensive approach to transport, particularly with regard to public transport and sustainable mobility options. Additionally, there are no clear guidelines in place for the development of urban transport systems in Bhutan. | **Establish clear frameworks for the development and management of urban transport systems to ensure efficient, sustainable, and inclusive urban mobility.**<br><br>Type:<br>Policy and Regulation | • Draft a comprehensive Urban Transport guideline that outlines strategies for sustainable urban transport development, including public transport and Non-Motorised Transport (NMT) across Bhutan. | **Continuously Learning** | **Medium**<br><br>Timeframe:<br>Medium term | **Lead:**<br>**DOST and DHS**<br><br>Support:<br>Thromde |
| Few new road projects are subject to climate resilience outcomes, and, there are limited to no resilience parameters integrated into road building due to financial limitations.<br>e.g. the selection and ranking criteria for prioritizing new road projects focus solely on cost-effectiveness and economic viability, overlooking the importance of resilience to climate risks. | **Develop resilience criteria for road transport sector infrastructure development.**<br><br>Type:<br>Policy and Regulation | • Update road design standards to include resilience measures and indicators.<br><br>• Update the road sector master plan to include resilience scoring (using the Principles for Resilient Infrastructure) and criteria for selecting and prioritizing new road projects.<br><br>*(Include climate resilience indicators as a core component, alongside cost-effectiveness and economic viability, cost and benefits when comparing the 'adaptation scenario' to the 'no-adaptation scenario').* | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**DOST**<br><br>Support:<br>DECC |

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| Key performance data that are useful for resilience tests on transport infrastructure and key functions are not readily available. | **Develop a standardized data collection and management system to ensure the availability and accessibility of key performance data for transport infrastructure, enabling effective resilience testing and monitoring of critical functions.**<br><br>Type:<br>Data & Assessment | • Collect key performance data (public transit routes, schedules, ridership, and service reliability, service coverage, transport facility age, projected demographic needs etc.).<br><br>• Improve/develop road asset database to include monitoring of road assets that are currently not in the asset database and update regularly. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**DOST**<br><br>Support:<br>BCTA & Thromde |
| Compliance with environmental regulations and best practices is insufficient, particularly related to construction practices (e.g. private access roads). | **Enhance coordination and monitoring for road planning and construction.**<br><br>Type:<br>Coordination<br>Policy and Regulation | • Develop systems for reporting and addressing non-compliance.<br><br>• Train local government in environmental and risk assessments and risk management. | **Environmentally integrated** | **Medium**<br><br>Timeframe:<br>Medium term | **Lead:**<br>**DOST/DOID**<br><br>Support:<br>LG<br><br>**Lead:**<br>**DOST/DOID**<br><br>Support:<br>LG |
| Insufficient EWS and monitoring for road networks. | **Install monitoring & Early Warning System: weather-responsive systems, landslide and flood sensors.**<br><br>Type:<br>Monitoring | • Identify road sections vulnerable to landslides and floods.<br><br>• Introduce and implement slope monitoring systems. | **Environmentally integrated** | **Medium**<br><br>Timeframe:<br>Long Term | **Lead:**<br>**DOST**<br><br>Support:<br>LG |
| Insufficient capabilities for research and development to inform policy and planning initiatives. | **Long-term policy & research: Invest in continuous research and development for innovative, sustainable materials & Strengthen global and regional collaborations for resilient transport systems.**<br><br>Type:<br>Capacity Building | • Invest in Capacity building for Transport officials.<br><br>• Promote and Implement Research Culture.<br><br>• Pilot sustainable projects. | **Continuously Learning** | **Medium**<br><br>Timeframe:<br>Long Term | **Lead:**<br>**DOST**<br><br>Support:<br>Universities |
| Low resiliency of road infrastructures due to poor quality materials, standardisation gaps and lack of climate resilience built into designs. | **Infrastructure Design & Upgrades: Stronger materials, elevated structures, permeable pavements.**<br><br>Type:<br>Infrastructure Project | • Collaborate with private firms on new technologies in the market.<br><br>• Update design standards based on the upgraded construction materials. | **Proactively Protected** | **High**<br><br>Timeframe:<br>Long Term | **Lead:**<br>**DOST**<br><br>Support:<br>Private firms, BSB, Technical Institutes (national & international) |

# B. ENERGY SECTOR

**The energy sector in Bhutan is predominantly driven by hydropower, which forms the backbone of the country's energy generation and export activities**. Despite the dominance of hydropower, other energy sources include petroleum, fuelwood, briquettes, and coal, which are utilized across the transport sector, manufacturing industries, and households. Additionally, Bhutan is exploring alternative green energy options, such as wind, solar, and thermal energies, to supplement its hydropower system. Bhutan's current hydropower installed capacity is 2,326 MW. With about 70% of the energy generated being exported to India, hydropower revenues constitute about 25% of revenues to the exchequer, offsetting much of the balance of payments with India and contributing about 7.5% of the country's gross domestic product. This substantial potential underscores Bhutan's strategic focus on enhancing its energy infrastructure to meet both domestic needs and export commitments.

**Bhutan's economic development is largely linked to the growth of its hydropower generation with a consistently high annual GDP share contribution (13.4% in 2022).** Hydropower development has not only helped the domestic sectors with improved livelihoods, but the industrial sector has been growing due to cheap energy availability. In addition to driving economic growth, it has boosted progress in meeting many of the country's social development objectives. Access to electricity has improved health outcomes and quality of life, especially in rural regions. Currently, nearly all households (99.71%) in Bhutan have access to electricity, with urban areas achieving 100% electrification and rural areas at 99.5%. Electricity is essential for the functioning of industries, homes, healthcare facilities, and technological infrastructure, powering critical services such as hospitals, schools, and communication networks.

# Energy Sector Institution and Policy Framework

*Table 16. Energy sector actors and policy framework*

| ENERGY | |
|---|---|
| **POLICYMAKERS** | The Department of Energy, MoENR, is the central coordinating agency and the focal point on all matters related to energy, power systems, and energy markets. The department is mandated to formulate national energy policies, plans, procedures, and guidelines for sustainable development, planning, construction, promotion, efficient utilisation, and management of energy resources and power systems, including cross-border energy trade. Additionally, the department is tasked with promoting the sustainable development, utilisation, and management of renewable energy resources with modern technologies, ensuring energy security, promoting reliable and safe energy supply, approving techno-economic clearances, enhancing productivity through energy efficiency, reviewing power markets, addressing threats to critical energy infrastructure, conducting research on clean technologies, reducing dependency on fossil fuels, providing technical advisory services on energy and climate change, introducing energy sector reforms, and facilitating resource mobilisation for energy projects.<br>*Source: Department of Energy, MoENR, RGoB.* |
| **REGULATORS** | The Electricity Regulatory Authority is responsible for developing regulations, standards, codes, principles, and procedures related to performance standards in the energy sector. These standards encompass technical and safety requirements for the construction, operation, and maintenance of generation, transmission, and distribution facilities. Additionally, the regulatory authority oversees tariff-setting, requirements for licensees' reporting, accounting, and issuance of information, system operation, levies, charges, or royalties to be paid by licensees. Their key functions also include monitoring the performance of licensees and ensuring their compliance with the provisions of relevant laws, regulations, standards, codes, licenses, and contracts approved by the authority. The authority is also responsible for establishing a dispute resolution process and settling disputes that may arise between licensees, and between licensees and customers within the energy sector.<br>*Source: Electricity Regulatory Authority, MoENR, RGoB.* |
| **OWNERS** | Infrastructure and asset ownership are shared among various agencies:<br>• The Department of Energy and its hydropower construction companies own the plants under construction including, if any, dams, tunnels, access infrastructures etc.<br>• The Druk Green Power Corporation Limited (DGPCL) own the commissioned hydropower plants and its power generation infrastructures. It also owns the mini hydropower plants under construction and its related infrastructures (Note: Druk Holding and Investments own 100% shares of the DGPC)<br>• The Bhutan Power Corporation Limited (BPCL) is the sole owner of all power transmission and distribution (T&D) infrastructures and assets in the country.<br>• The petroleum-based energy assets are owned and operated by private companies |
| **OPERATORS** | The hydropower plants under construction are either owned by the projects including private companies in the case of Inter-Governmental, Joint Venture, Public Private Partnership modalities or by DGPCL projects.<br>The DGPCL and its individual plants (Basochu, Kurichu, Mangdechu, Chukha, Tala Plants) are the operators of these commissioned plants.<br>BPCL operates its transmission and distribution networks and assets within the country. |
| **KEY POLICIES** | The Bhutan Sustainable Hydropower Development Policy 2020 aims to expand capacity to at least 5,000 MW by 2030, enhancing both domestic energy security and export capabilities. The energy sector is also guided by the Alternative Renewable Energy Policy and an Energy Efficiency and Conservation Policy. The Electricity Act of Bhutan sets the legal framework for regulations, including tariffs and safety standards, by establishing a regulatory authority responsible for drafting regulations, guidelines, and master plans. |

# Energy Sector Vulnerabilities

**Bhutan's hydropower and, therefore, the bulk of the energy source is vulnerable to several factors, including geological conditions, climate, weather, increasing demand, technological constraints, etc.** At the generation phase, hydropower is highly dependent on seasonal and annual precipitation patterns. Variability in water flow, influenced by climate change, leads to significant fluctuations in power generation capacity. Meanwhile, there is a growing domestic demand for electricity, driven mainly by industrial growth and, to a certain extent, by a rise in population. This increasing demand, in conjunction with water flow variability, surpasses the current generation capacity, especially during periods of low water availability. For example, Bhutan imports energy from India during the lean season. In 2022, Bhutan imported 240 MU of energy during the lean period at a cost of Nu. 798 million at an average import cost of Nu. 3.32 per unit (including charges/fees).

## THE STRESS TEST ANALYSIS REVEALED THE FOLLOWING VULNERABILITIES

Current run-of-the-river hydropower plants are most susceptible to droughts due to climate change. Other extreme climate events, such as glacial lake outburst floods, heavy rainfall, and flash floods, further exacerbate these challenges, for instance, by increasing sedimentation and debris in rivers that have an impact on the operational lifespan of assets. Bhutan's mountainous terrain and seismic activity also make hydropower assets susceptible to loss and damage. Drought occurs when there is an imbalance between water supply and demand. The Standardized Precipitation Index (SPI) measures how observed precipitation (rain, hail, snow) deviates from the climatological average over a specific period. Figure 5 presents a 3-month SPI derived from the GPM-IMERG dataset, based on a climatological period from 2000 to 2020[3,4]. UNOSAT's drought exposure assessment indicates that 9 power substations are exposed to drier-than-average conditions. Additionally, approximately 101 km of power transmission lines are located within areas prone to heightened dryness.

Bhutan's electricity transmission and distribution (T&D) network is predominantly susceptible to geological events such as earthquakes and landslides, but also to fire and flash floods. These natural hazards pose significant risks to the integrity and reliability of the T&D infrastructure, causing electrical failures and prolonged disruptions in power supply as well as necessitating extensive repairs. Simultaneously, the T&D systems are identified as potential fire hazards, exposing surrounding infrastructure, settlements, and forests.

Energy generation and T&D functions have a medium to high dependence on road network (high), transport cargo and passengers (high), water supply (medium), wastewater management (medium), internet access and service (medium), health care (medium), and education facilities (medium). Meanwhile, any failure in the generation and T&D functions will have significant implications on technology-dependent economic and social sectors with far-reaching consequences, affecting economic productivity and health and education outcomes. Internet routing, access and connection, air transport, education and health services have a high dependence on electricity generation and T&D. Water supply, wastewater management, and surface transport (cargo and passenger transport) have a medium dependency on electricity.

3. *The SPI, a widely used drought index, is valuable for assessing how current precipitation levels compare to historical averages.*
4 *National Integrated Drought Information System (NIDIS) provided by the National Oceanic and Atmospheric Administration (NOAA), https://www.drought.gov/about#:~:text=The%20National%20Oceanic%20and%20Atmospheric%20Administration%E2%80%99s%20(NOAA's)%20National*

*Figure 5. Energy sector assets exposed to drought. Source: National Integrated Drought Information System (NIDIS) provided by the National Oceanic and Atmospheric Administration (NOAA) and DLGDM.*

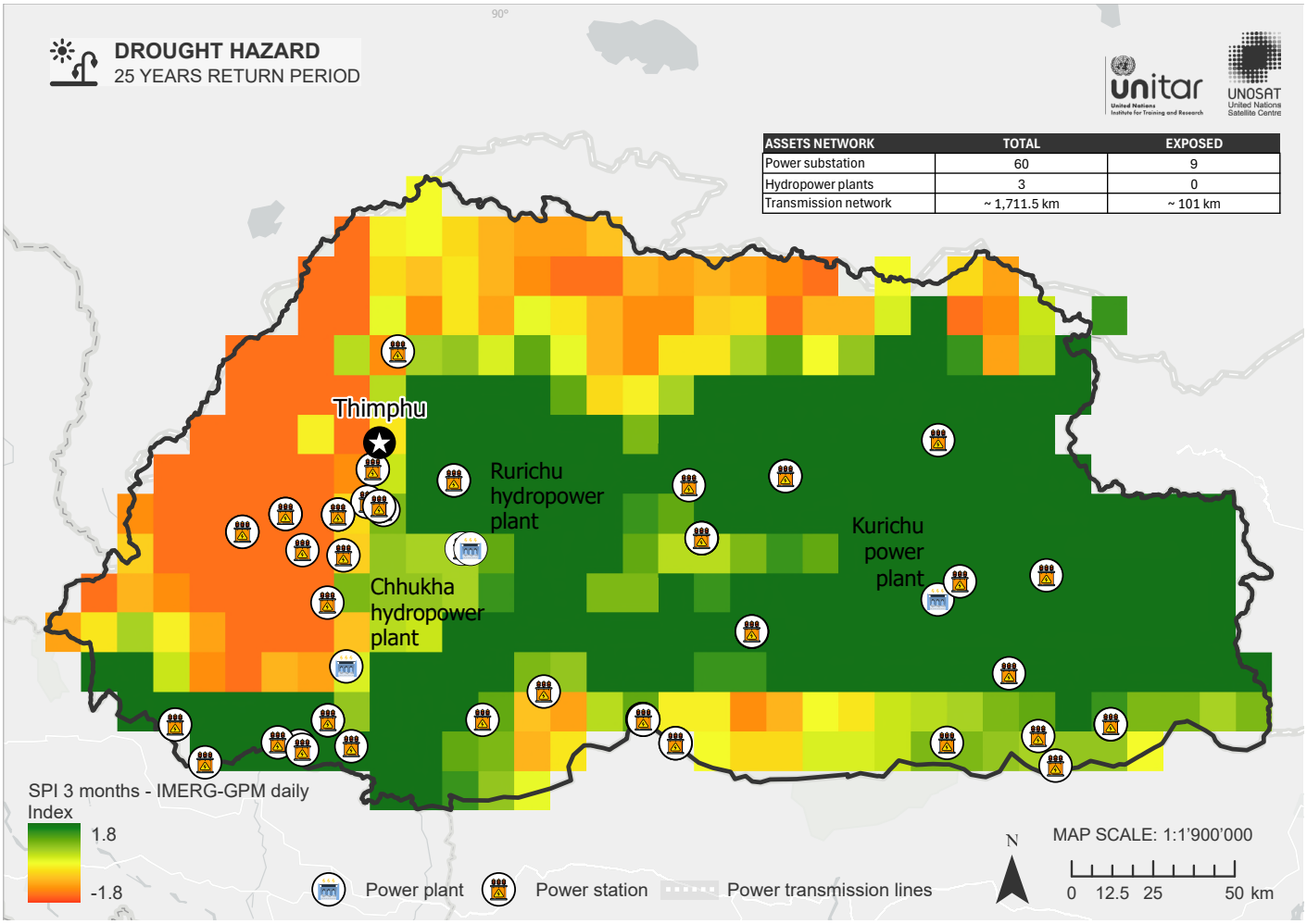



*Table 17. Electricity generation, transmission & distribution dependency & rationale.*

| HIGH | MEDIUM |
|---|---|
| **Build and maintain bridges and tunnels** *(The construction and maintenance of bridges and tunnels are critical for ensuring that electricity infrastructure can be established and maintained across diverse and often challenging terrain)* | **Supply, treat and distribute water** *(Functional water supply and redundancies are important mainly for operational purposes)* |
| **Transmit and distribute electricity** *(Electricity transmission & distribution is key to ensuring that generated power reaches consumers, industries, and other critical sectors)* | **Manage wastewater** *(Functional water supply and redundancies are important mainly for operational & maintenance related to personnel)* |
| | **Transport cargo and passengers by air** *(Mainly related to its role in the rapid deployment of specialized equipment or personnel during emergency management)* |
| | **Transport cargo and passengers by road** *(Access to power plants and T&D infrastructure, transport of parts and equipment needed for maintenance and repair supporting the electricity grid)* |
| | **Provide internet routing, access, and connection** *(Vital for modern electricity grid management, especially with the integration of smart grid technologies that rely on real-time data and remote monitoring)* |
| | **Build and maintain health care facilities** *(For health care of personnel involved in generation and T&D)* |

# Current Resilience Measures

**Resilience measures during the construction and generation phases of hydropower are well-advanced, leading to proactive strategies for risk reduction and enhanced resilience.** Some of the identified measures include:

*Feasibility studies and investigations:*

Comprehensive feasibility studies and investigations are carried out for hydropower project development. These studies include detailed hydrological assessments to account for varying flow patterns, geological and geotechnical investigations, climate parameters, GLOF etc. to assess and mitigate potential risks.

*Maintenance and operation:*

To ensure the continuous and smooth operation of power plants, DGPCL implements periodic maintenance throughout the year, with annual maintenance scheduled during the lean season when river flows are at their lowest. An essential part of minimising downtime and reducing generation loss involves maintaining a well-stocked inventory of critical spare parts, which allows for rapid replacement and repair without significant delays due to procurement issues.

*Supportive infrastructure and modernization:*

Bhutan Hydropower Services Limited, a subsidiary company of DGPCL, specializes in the repair and manufacturing of hydro turbine runners and associated components and facilitates timely repair and supply of required electrical and mechanical (E&M) parts. Regular condition assessments of power plants are conducted, with renovations and modernisation projects initiated as needed to maintain operational efficiency.

The gradual automation of power plants, managed by Bhutan Automation Engineering Limited, involves the phased installation of SCADA systems, which enhances operational control and monitoring capabilities. Additionally, the Hydropower Research and Development Centre conducts regular testing of E&M equipment across power plants to ensure their reliability and performance.

*Emergency preparedness and risk management:*

A Business Continuity Plan is in place, and an “Emergency Action Plan” for power plants and corporate offices details both preventative measures and post-disaster actions. Fire safety and disaster management teams at power plants are trained to ensure safety and prompt response in the event of a disaster.

*Renewable energy integration:*

Investments in reservoirs, pumped storage projects and water diversion schemes are being considered to increase water storage capacity, ensuring a reliable water supply during lean seasons when natural river flows are reduced. Renewable alternatives such as solar photovoltaic (PV) are being explored and piloted to augment lean flows during dry months, ensuring consistent electricity production during lean months.

# Gaps and Implementation Plan

*Table 18. Energy sector Implementation Plan*

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| There is some slack in grid stability, real-time monitoring, and facilitating quick responses to outages in transmission and distribution services. | **Improve resilient and reliable energy infrastructure using real-time grid monitoring and automation systems to improve real-time diagnostics, and facilitate faster responses to outages in transmission and distribution services.**<br><br>Type:<br>Technology & Automation | • Adopt and use automation systems in substations to monitor and control stability.<br>• Adopt and use smart grid and smart meter technologies for end users.<br>• Depending on diverse sources of energy, encourage ring distribution systems wherever feasible. | **Adaptively Transforming** | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**BPC**<br><br>Support:<br>ERA, BSB, Thromde, BQPCA |
| | | • Construct GIS substations for compact, safer and O&M efficiency. | | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**BPC**<br><br>Support:<br>DOE, BPSO |
| Current practices do not align with the safety codes published by the Bhutan Standards Bureau (BSB), resulting in a fragmented approach across different stakeholders in safety practices and protocols. | **Enhance compliance with safety standards of BPC/ BSB by standardizing and establishing mechanisms to ensure safety code alignment.**<br><br>Type:<br>Policy and Regulation, Capacity Building and Coordination | • Update BPC's safety codes.<br>• Update BPC's SOPs. | **Proactively Protected** | **High**<br><br>Timeframe:<br>Short term | **Lead:**<br>**ERA, BPC and BSB**<br><br>Support:<br>Thromde, BQPCA |
| | | • Train and build capacity on safety codes and SOPs.<br>• Conduct regular monitoring and audits to improve compliance. | | **High**<br><br>Timeframe:<br>Short term | **Lead:**<br>**ERA, BPC and BSB**<br><br>Support:<br>Thromde, BQPCA |
| | | • Launch targeted awareness campaigns to educate households about the importance of maintaining safe electrical infrastructure within their homes.<br>• Ensure hiring of qualified/certified workers to carry out the work.<br>• Build awareness of standards and requirements for implementing agencies.<br>• Enhance household resilience against electricity-related accidents through community safety awareness programmes and campaigns. | | **Medium**<br><br>Timeframe:<br>Short term | **Lead:**<br>**BPC and ERA**<br><br>Support:<br>LG and Communities |

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| Risk reporting is voluntary rather than mandatory, leading to inconsistent availability of infrastructure risk information and thereby limiting the ability of stakeholders to make risk-informed investment decisions. | **Establish standardized mandatory regulatory requirements for risk reporting across electricity transmission and distribution sectors.**<br><br>Type:<br>Policy and Regulation | • Implement regulatory requirements for mandatory, standardized risk reporting by infrastructure operators and owners, ensuring consistent availability of risk information to support informed decision-making and investments that enhance resilience.<br>• Establish accountability mechanisms and regular audits in the context of electrical accidents.<br>• Develop mechanisms for public disclosure of accident investigations and outcomes for transparency and recommendations for improvement. | **Shared Responsibility** | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**ERA**<br><br>Support:<br>Department of Energy, BPC |
| | **Establish feedback loops and mechanisms to improve resilience.**<br><br>Type:<br>Monitoring | • Conduct regular assessments to measure their effectiveness and use these evaluations to refine and adjust strategies over time. | **Socially Engaged** | **Medium**<br><br>Timeframe:<br>Short Term | **Lead:**<br>**ERA**<br><br>Support:<br>DGPC, BPCL |

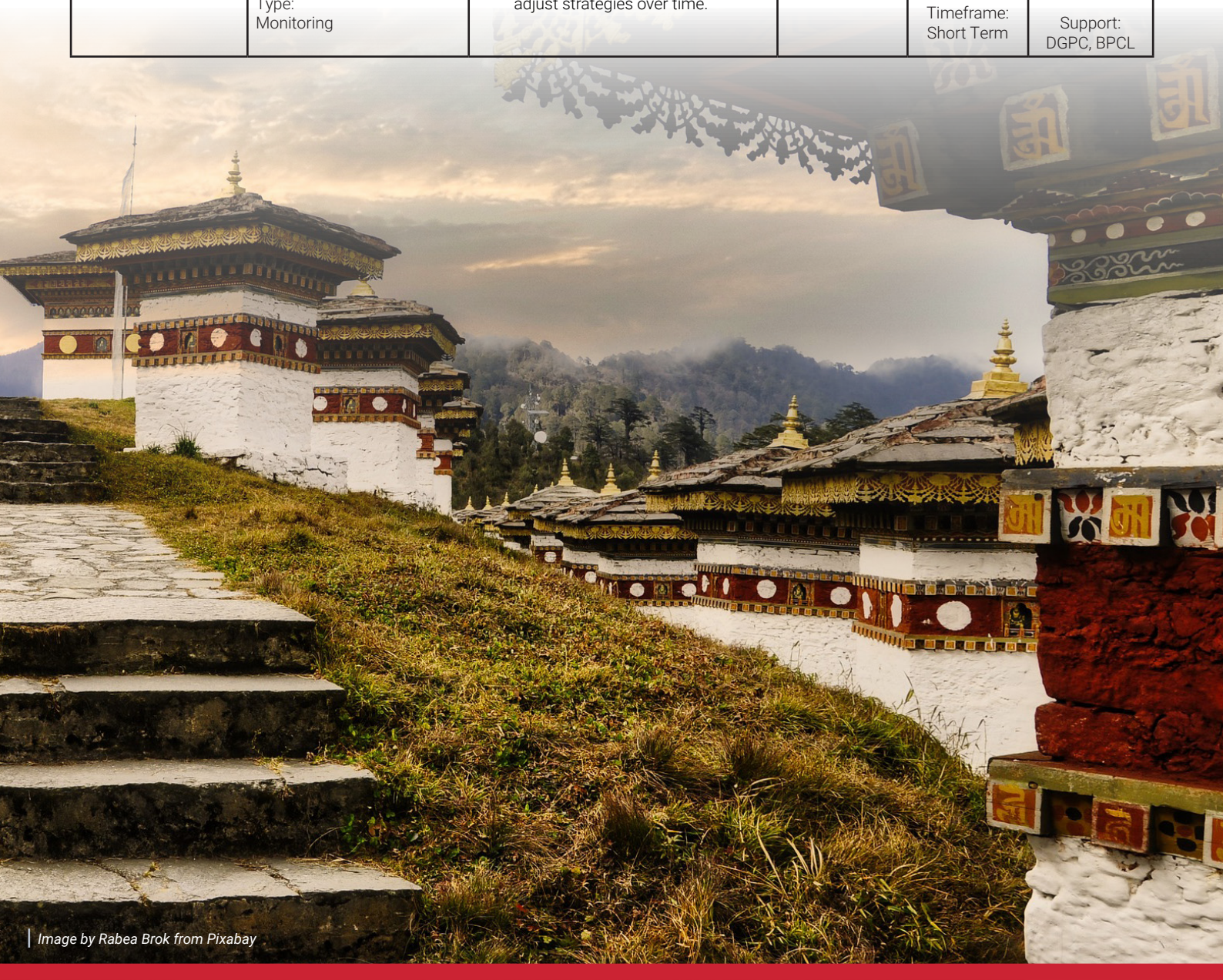


*Image by Rabea Brok from Pixabay*

# C. WATER SECTOR

**Despite Bhutan's abundance of freshwater resources, the country experiences localized and seasonal water shortages that affect both rural and urban communities**. Water resources are fully centralized and publicly owned with minimal private sector involvement. However, water management is supported by a multi-stakeholder approach that involves various governmental bodies, each tasked with specific aspects of water resource development and management, highlighting the sector's complexity.

**Water is a significant economic driver for Bhutan, supporting key sectors such as agriculture, hydropower, tourism, and other water-related industries.** The agriculture sector, which employs 43.7 per cent of the population, relies heavily on water supply for irrigation and livestock. The hydropower sector, a major contributor to Bhutan's GDP (13.4% in 2023) and a significant source of export revenue is entirely dependent on the abundant river systems. Additionally, water is crucial for industries that rely on water-intensive processes. Critical social sectors such as health and education are also highly dependent on the provision of a safe and reliable water supply. At the household level, sanitation coverage stands at 78 per cent and 99.7 per cent have access to improved water sources, with rural water access at 92.46 per cent[5].

An in-depth analysis of the water sector was conducted in collaboration with relevant stakeholders, leading to the following insights and recommendations.

5. Gross National Happiness Commission (2021). Bhutan's Second Voluntary National Review Report on the Implementation of the 2030 Agenda for Sustainable Development.

# Water Sector Institutions and Policy Framework

*Table 19. Water sector actors and policy framework.*

| WATER | |
|---|---|
| **POLICYMAKERS** | National Environment Commission (NEC)<br>The Water Act of Bhutan 2018 established the NEC as the apex independent authority to set the water sector vision, policy, guidelines, and plans. The Commission has the mandate to coordinate national integrated water resources management, issue directives for restorative, corrective, or mitigating measures, planning, protection, and management at various levels, promote water education, research, or studies, advocate for water-friendly and water-efficient technologies, and integrate water into the national policy, plan, and programs. The Commission directs: **(i) the MoIT** (erstwhile MoWHS) as the competent authority for the overall planning, implementation and management of infrastructure for drinking water supply and wastewater for urban areas.<br>(ii) The **Ministry of Health** as the competent authority for the overall planning, implementation and management of infrastructure for drinking water supply and sewage for the rural areas in collaboration with the local governments, and monitoring the quality of drinking water in the country.<br>(iii) The **Department of Agriculture under MoAL and Department of Forest and Park Services under MoENR** are directed to carry out visioning, policy, guidelines and planning for irrigation system, watershed and wetland management. |
| **REGULATORS** | Department of Water, MoENR<br>As per the Water Act of Bhutan 2018, the water sector is regulated by the National Environment Commission assisted by its **secretariat** to carry out its functions. With the transformation exercises within the civil service, the Department of Water has the directives to oversees the integration, coordination and regulation of water resource management strategies across different ministries and departments. It sets and enforces water quality standards and guidelines, effluent discharge standards, and minimum environmental flows for watercourses and is responsible for establishing procedures for monitoring water quality standards and discharge standards and monitoring overall compliance by competent authorities, ensuring adherence to the provisions of the Water Act.<br>The Act also empowers the thromdes (municipalities) to set water tariffs and may settle disputes related to the jurisdiction of the thromde. |
| **OWNERS** | The ownership of water supply and wastewater infrastructure varies among **local governments (thromdes, dzongkhags, gewogs), communities and households.** |
| **OPERATORS** | Different operators are involved in the sector, including local governments, private sectors, and Water User Groups.<br>Thromdes (local government) are responsible for the operations of water and sewage treatment plants, and cost recovery by setting tariff and user charges in urban areas.<br>Water User Groups may exist in villages and/or gewogs (local government) are the operators for rural water supply infrastructures. |
| **POLICY** | The Water Act 2011 and the Waste Prevention and Management Act 2009 are the regulatory frameworks with provisions for standards, rights and responsibilities of different stakeholders. Relevant strategies are available to provide the framework for implementation. |

# Water Supply Vulnerabilities

**The water sector faces several vulnerabilities across various aspects and water parameters. As a cross-cutting sector, the management of water resources involves multiple agencies, leading to challenges in inter-agency coordination.** There is a lack of managed water storage and other related infrastructure further exacerbating these shortages. Existing water infrastructure requires resilience improvements and upgrades to meet current and future demands.

Seasonal and spatial water availability exacerbates the problem in Bhutan, where abundant monsoon rains quickly drain away due to the steep terrain. This leads to significant water shortages during the dry months, and there are increasing reports of local water scarcity during this period. The rising demand for water, driven mainly by expanded irrigation, urbanisation, and water-dependent industries, further intensifies the competition for water.

**The water sector is highly sensitive to climate variations, with projections indicating potential increases in extreme weather events and their impact on water resources.** Climate change compounds the existing issues by altering precipitation patterns and increasing the frequency and intensity of extreme weather events, which disrupt both the quantity and quality of water available. Water assessments already indicate concerning trends, with 0.9% of water sources dried up and 25.1% in a drying state out of a total of 7,399 mapped water sources[6].

**The stress test analysis shows drought as the most significant risk to water supply affecting households, agriculture, water-based industries, and health outcomes (see Figure 6)**. Various aspects of water supply including infrastructure, assets, and water quality have a medium to high risk from floods, GLOF, earthquakes, landslides and waterborne epidemics. For example, the 10 August 2024 flood in Dangrira severely affected water supply systems, and the Thimphu Thromde responded by engaging water tankers to supply household consumption.

Besides the direct impact of hazards, the stress test exercise identified that the water supply function in Bhutan has a medium dependency on services of transport, electricity and the ICT sector (see Table 20). This implies that any disruptions in these functions will have an impact on water supply, underscoring the need to consider cascading risks in analysing water supply resilience.

6. *Royal government of Bhutan (2023), National Adaptation Plan 2023.*

*Figure 6. Water supply vulnerability & exposure to hazards*

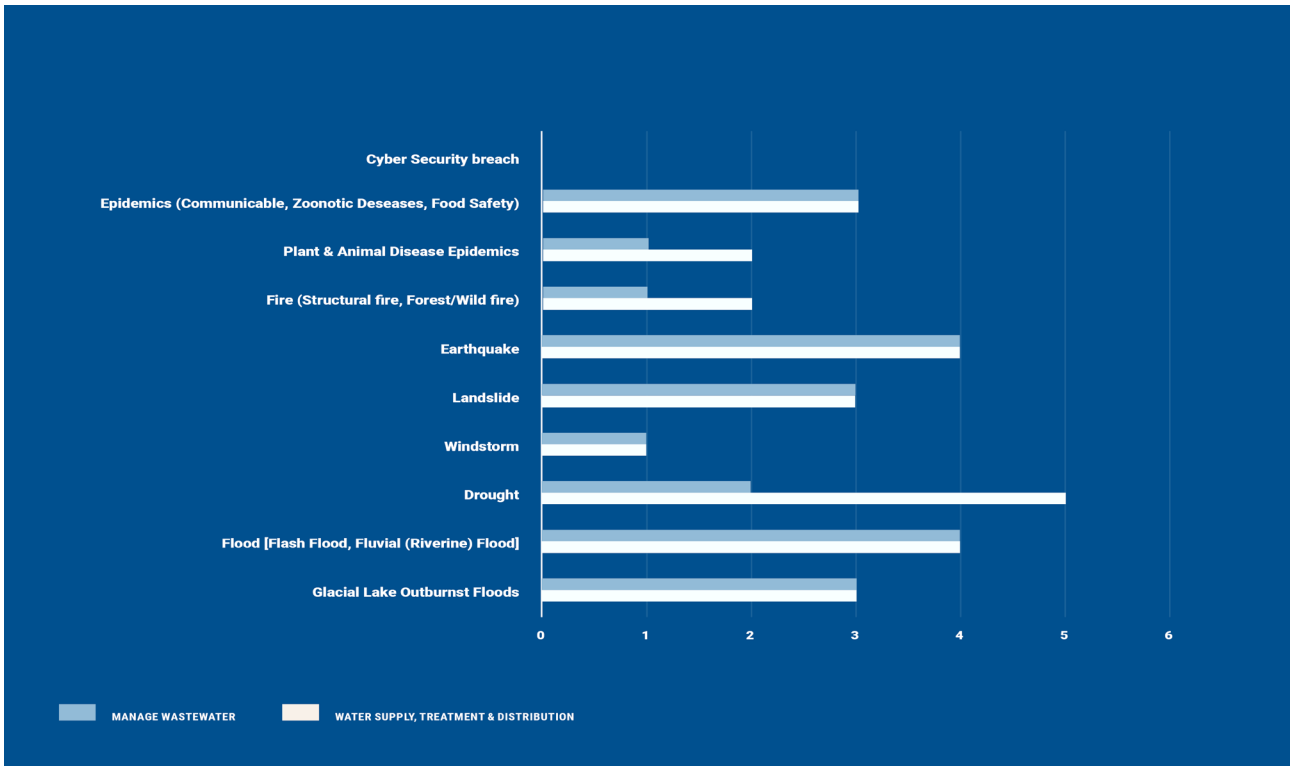



*Table 20. Water supply dependencies to other critical functions with rationale.*

| HIGH | MEDIUM |
|---|---|
| **Manage wastewater**<br>*(Mainly related to water quality issues from runoff and seepage of unmanaged wastewater)*<br><br>**Build and maintain schools facilities**<br>**Build and maintain health care facilities**<br>*(While healthcare facilities are highly dependent on water supply, the health sector also provides water supply and sanitation services including water testing services through its WASH programme)* | **Transport cargo and passengers by air**<br>*(Any disruption in cargo and passenger transport will affect access to water infrastructure including O&M)*<br><br>**Build and maintain bridges and tunnels**<br>*(Access to water infrastructure including O&M)*<br><br>**Generate and Transmit**<br>*(At the household level, water supply uses electricity-powered pumps and therefore, failures in electricity supply will disrupt water supply)*<br><br>**Provide Internet Routing, Access, and Connection**<br>*(As water supply moves towards automation, its functions including communication are dependent on internet connectivity and mobile networks including O&M)* |

## WASTEWATER MANAGEMENT

In Bhutan, the primary point sources of wastewater are households and commercial establishments, institutions (blackwater and greywater), hospitals/health centres, industries (heavy metals, chemical and other pollutants), and sewage treatment plants. Nonpoint sources include stormwater, agricultural runoff, mining wastewater, monsoon flash floods, and glacial lake outburst floods. The composition of wastewater varies significantly across different regions, predominantly influenced by residential and commercial activities.

# Wastewater Management Vulnerabilities

**Despite the significant investments made in managing wastewater, challenges remain in extending effective coverage and ensuring environmental compliance, especially in remote areas.** Wastewater treatment coverage varies significantly between urban and rural areas due to differences in infrastructure and resource availability. Urban centres have more advanced and centralized sewage treatment plants catering to most households, including the introduction of eco-friendly and decentralized wastewater treatment systems. Rural areas primarily rely on septic tanks, but inadequately treated pollutants are allowed to run off, contaminating soil, surface and groundwater sources.

**The stress test exercise identified drought, earthquake, and flood as the most significant hazards for Bhutan in terms of impact on the critical functions of managing wastewater.** The stress test results also showed risks from earthquakes and landslides disrupting wastewater infrastructure and systems.

The wastewater system is also dependent on consistent water supply, which means that any disruption in water supply due to environmental changes (drought, flood and heavy rainfall) directly affects the efficiency of wastewater management. Meanwhile, any failure and compromise in the wastewater system has a direct implication on the quality of drinking water and cascading impacts on the social sectors especially related to human and livestock health. Table 21 shows the dependencies of wastewater management on other critical functions that need to be considered for building resilience in the system.

*Figure 7. Perception of wastewater management risks level by hazards*

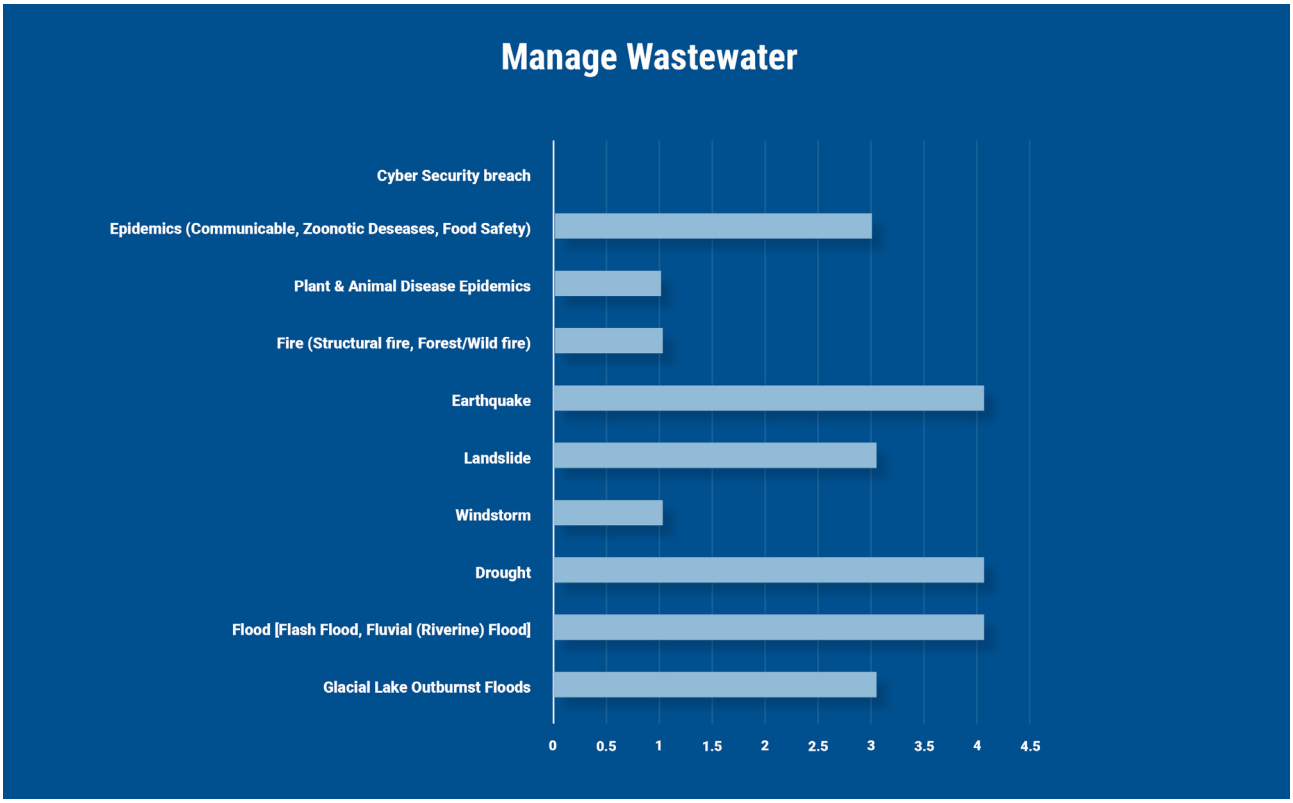


*Table 21. Wastewater management dependencies and rationale.*

| HIGH | MEDIUM |
|---|---|
| **Supply water, treat and distribute**<br>*(Technical performance of wastewater treatment is dependent on water supply)* | **Transport cargo and passengers by air and road**<br>*(Any disruption in cargo and passenger transport will affect access to wastewater infrastructure including O&M)*<br><br>**Build and maintain bridges and tunnels**<br>*(Access to wastewater infrastructure including for O&M)*<br><br>**Generate and transmit electricity**<br>*(The technical performance of wastewater treatment is dependent on water supply powered by electricity, which has an impact on wastewater management)*<br><br>**Build and maintain school facilities**<br>**Build and maintain health care facilities**<br>*(This is mainly related to wastewater generated from health facilities and therefore its management is dependent on the facilities system)* |

# Current Resilience Measures

**A range of resilience measures are currently in place to respond to disruptions in water supply services and wastewater management:**

- *Clear roles and responsibilities for water infrastructure development:* There is improved clarity in roles for water infrastructure development for more than 15 stakeholder agencies as per the Water Act. Local governments are specifically mandated to build and maintain water supply and wastewater infrastructure, including during disruptions. Designated technicians are stationed at the Thromde and Dzongkhag levels to ensure operation and maintenance. The Department of Infrastructure Development holds the responsibility for designing and implementing water and wastewater infrastructure, including flood adaptation structures to protect critical facilities like wastewater treatment plants and water intake structures.
- *Government prioritization of water sector issues:* The government has prioritized water sector issues as evidenced by the key initiatives in the National Adaptation Plan, the Water Flagship Program, and the inclusion of water as a critical element in the Five-Year Plans. These efforts align with the Bhutan Integrated Water Resources Management (IWRM) framework, ensuring that water resources are managed sustainably and efficiently across various sectors.
- *Investment in resilient water infrastructure:* Development partners have committed significant investments to support resilient water infrastructure development in Bhutan, particularly in emerging urban areas such as the Secondary Township Urban Development Project.
- *Rainwater harvesting initiatives:* Rainwater harvesting is practised as a resilience measure, particularly in communities, schools, and monastic institutions.
- *Water supply redundancies in urban areas:* Urban communities in Bhutan commonly practise water supply redundancies to ensure continuous access to water. Thromdes frequently use water tankers to supplement the water supply during shortages. This practice is a critical component of urban water management, helping to mitigate the impact of water supply disruptions.
- *Water, Sanitation, and Hygiene (WASH) programs:* The Ministry of Health prioritizes WASH programs in homes, schools, and monastic institutions across Bhutan to promote public health and preventing waterborne diseases.

# Gaps and Implementation Plan

*Table 22. Water sector Implementation Plan*

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| A significant gap exists in the comprehensive understanding and coverage of water resources, water supply, quality, and condition. | **Enhance water supply performance understanding including sources, water supply, quality, infrastructure performance etc.**<br><br>Type:<br>Data Assessment | • Assess the number of drying water sources, focusing on reviving springs and developing interventions for those at risk, along with measures to sustain them.<br>• Develop a GIS-based nationwide inventory of water and wastewater infrastructures.<br>• Develop and maintain water supply and wastewater system database. | **Continuously Learning** | **Medium**<br><br>Timeframe: Long Term – 3-5 years | **Lead: DOW & MOIT**<br><br>Support: Thromde and LG |
| Dzongkhags and thromdes lack a comprehensive asset management and maintenance programme for drinking water systems, including risk profiling and prioritization for high-risk areas, data management and decision-making. | **Establish a comprehensive asset management and maintenance programme for drinking water systems in dzongkhags/thromdes, incorporating risk profiling and prioritising improved treatment in high-risk areas.**<br><br>Type:<br>Data and Monitoring, Infrastructure Project and O&M, and Data Assessment & Monitoring | • Establish monitoring and risk profiles for drinking water in dzongkhags/thromdes, and identify priority areas for improved treatment. | **Continuously Learning** | **Medium**<br><br>Timeframe: Short Term (1 Year) | **Lead: MOIT and Thromde**<br><br>Support: LG |
| | | • Initiate replacement programme for galvanised iron pipes.<br>• Carry out R&D and adoption of improved technology to improve water quality, | **Continuously Learning** | **Medium**<br><br>Timeframe: Short Term (1 Year) | **Lead: MOIT and Thromde**<br><br>Support: LG |
| | | • Upgrade monitoring and control systems for water infrastructure, including SCADA systems, and ensure the collection of real-time water quality data.<br>• Develop an online Water and Sanitation Information system (WASIS). | **Continuously Learning** | **Medium**<br><br>Timeframe: Short Term (1 Year) | **Lead: MOIT and Thromde**<br><br>Support: LG |

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| Due to financial constraints, resilience measures such as consideration of climate risks, redundancy measures and safe-to-fail systems are only partially considered or absent in water projects. | **Enhance resilience measures for water and wastewater infrastructure through targeted investments that consider climate risks, safety and redundancies.**<br><br>Type:<br>Policy, Project Design and Monitoring, Financing Capacity | • Update standards to adopt ASCE (American Society of Civil Engineers) risk category IV or national equivalent in national infrastructure guidelines. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Short Term – 1 year | **Lead:**<br>**DHS and DOID**<br><br>Support:<br>DOW, Thromde, LG, NCHM |
| | | • Consider lifecycle hazards, improve safety baselines, safe-to-fail systems and redundancies in planned water infrastructure projects. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Short Term – 1 year | **Lead:**<br>**DHS and DOID**<br><br>Support:<br>DOW, Thromde, LG, NCHM |
| | | • Access and target development and climate funds and development of financial capacity to meet O&M requirements. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Short Term – 1 year | **Lead:**<br>**DHS and DOID**<br><br>Support:<br>DOW, Thromde, LG, NCHM |
| Lack of suitably qualified experts, clear guidance and resources for local governments' water and wastewater management responsibilities. | **Enhance the capacity of local governments in water and wastewater management.**<br><br>Type:<br>Policy and Capacity Building | • Draft guidelines for local government water managers and support their implementation. | **Adaptively Transforming** | **High**<br><br>Timeframe:<br>Short – Medium Term | **Lead:**<br>**LG**<br><br>Support:<br>DOID (infrastructure development)<br>DOW (resource assessment & management) |
| | | • Targeted training for local government and support for dedicated water expertise in local governments. | **Adaptively Transforming** | **High**<br><br>Timeframe:<br>Short Term – 6 months | **Lead:**<br>**DoW, DECC, MOIT**<br><br>Support:<br>LGs and Thromdes |
| | | • Capacity building of the water treatment plant operators and water caretakers for RWSS with essential skills for O and M. | **Adaptively Transforming** | **Medium**<br><br>Timeframe:<br>Short Term – 6 months | **Lead:**<br>**DoW, DECC, MOIT**<br><br>Support:<br>LGs and Thromdes |
| | | • Support water sector organisations to build the capacity of staff and community members involved in water management through increased training and education. | **Adaptively Transforming** | **Medium**<br><br>Timeframe:<br>Short – Medium Term | **Lead:**<br>**Local governments**<br><br>Support:<br>DOID (infrastructure development)<br>DOW (resource assessment & management) |

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY / TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| Lack of clear and robust emergency management and contingency plans for water/wastewater assets and services. | **Improve emergency management and contingency plans for water and wastewater services.**<br><br>Type:<br>Policy and Governance | • Draft contingency plans for each critical water function.<br><br>• Draft and maintain standard operating procedures for critical water functions. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Medium Term (1-3 Years) | **Lead: MOIT**<br><br>Support:<br>DOW, DHS, LG |
| Existing water policies are inadequate and outdated. | **Establish formal mechanisms for clarification of roles and responsibilities, collaboration and information sharing across the water sector.**<br><br>Type:<br>Policy | • Update the Water Policy to ensure all relevant agencies (including those recently established) are referred to.<br><br>• Provide a definition of "the competent authority". | **Continuously Learning** | **Medium**<br><br>Timeframe:<br>Medium Term – 1-3 years | **Lead: DoW**<br><br>Support:<br>MOIT, Thromde, LG, GovTech |
| Bhutan shares water boundaries with China and India but does not have collaborative relationships with China. | **Strengthen collaborative efforts and explore channels or third-party mediators to review and assess transboundary water catchments and disaster impacts.**<br><br>Type:<br>Coordination | • Review current arrangements in relation to water catchments and cross-boundary disasters that impact water assets. | **Adaptively Transforming** | **Medium**<br><br>Timeframe:<br>Short Term | **Lead: DoW**<br><br>Support:<br>All water stakeholders |
| | | • Conduct stress testing of cross-boundary water assets to identify transboundary vulnerabilities and issues. | **Continuously Learning** | **Low**<br><br>Timeframe:<br>Short Term | **Lead: DoW**<br><br>Support:<br>All water stakeholders |
| Challenges in planning and maintaining water, wastewater, and flood protection infrastructure, without standardized guidelines for risk assessment and resilience elements in infrastructure development. | **Standardize design and planning for water infrastructure/flood mitigation projects by establishing clear guidelines on risk assessment, climate change adaptation and cost-benefit analysis.**<br><br>Type:<br>Policy/Guidelines | • Draft standards and guidelines for water infrastructure | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Long Term (3-5 years) | **Lead: MOIT, DHS, DOID**<br><br>Support:<br>LG |

# D. INFORMATION, COMMUNICATION AND TECHNOLOGY (ICT)

**There is a growing focus on Information and Communication Technology for development prompting Bhutan to formulate national-level ICT policies, legal instruments and investments in infrastructure and skills.** As a result, Bhutan, in recent years has achieved a high level of ICT access, closing the digital divide gap. The country has established an extensive fibre-optic backbone, achieving high mobile population coverage. Close to 99 percent of households use mobile phones in Bhutan and about 95 percent own smartphones[7]. Bhutan launched an ambitious ICT flagship programme for the 12 FYP, aimed at leveraging ICT to create a smart and inclusive society. This initiative encompasses various aspects such as digitalization, the adoption of cutting-edge IT technologies like Artificial Intelligence (AI), robotics, big data, and the Internet of Things (IoT), as well as the implementation of smart contracts. Furthermore, the programme prioritizes enhancing the capacity and capability of the ICT sector, including infrastructure development.

7. *National Statistical Bureau, RGoB (2022), Bhutan Living Standard Survey*

# ICT Institutions and Policy Framework

*Table 23. ICT actors and policy framework*

| ICT | |
|---|---|
| **POLICYMAKERS** | GovTech Agency<br>The Information, Communications and Media Act of Bhutan 2018 requires the GovTech Agency (Erstwhile Ministry of Information and Communication) to formulate legislation, policies, and plans related to ICT and media matters; propose appropriate codes and standards for ICT apparatus including radio communication apparatus for approval by Bhutan Standards Bureau; approve Rules and Regulations to implement various provisions of this Act including policy guidelines on tariffs and rates. |
| **REGULATORS** | Bhutan Information, Communication and Media Authority (BICMA)<br>The ICMA 2018 mandates the BICMA to regulate the ICT and media sector. The Authority has the power to issue directions, guidelines, or codes of practice consistent with the Act and Rules and Regulations to carry out its functions effectively. Its functions include granting licenses, certificates, and permits for ICT and media facilities and services as well as ensuring compliance with international, regional, and national standards related to equipment, technical standards, and environmental health and safety standards.<br>The ICMA also regulates interconnection and sharing of infrastructure among ICT facility providers, promotes competition, and ensures interoperability and efficient use of ICT facilities and services. It protects consumers and oversees the accounting systems of public ICT providers and media services providers.<br>It conducts periodic circulation audits of print media firms and works to create a conducive environment for the development of a competitive and dynamic ICT services market. The ICMA also aims to ensure universal access to all ICT services at affordable rates and fosters technological innovation in the ICT and media sectors. The adoption of Rules and a Code of Conduct contributes to the efficient functioning of the Authority.<br>Source: Information, Communication and Media Act 2018 period. |
| **OWNERS** | GovTech Agency (govt) owns and operates e-government infrastructure (GIS, Digital Identity Systems. etc) and cybersecurity infrastructure.<br>Bhutan Telecom Ltd (SoE) and Tashi InfoComm Private Limited (Tashi Cell) (Private) are two companies providing telecommunication and internet services in Bhutan. Both companies may own or share cellular towers, fibre networks, and international connections.<br>The Bhutan Broadcasting Service Corporation (SOE) is the only broadcast entity in the country.<br>Private companies provide media communications (cable operators) and ISPs.<br>Royal Bhutan Police owns and operates radio networks.<br>Various sectors have ownership over data systems related to their mandates. E.g. DLGDM owns and operates a Disaster Management and Information System. |
| **OPERATORS** | Bhutan Telecom Ltd (SoE) and Tashi Cell (Private) as telecommunication and internet service providers operate telecommunication infrastructure (satellites, fibre-optic networks, mobile communication networks).<br>Other private entities that provide media communications (cable operators) and ISPs.<br>Royal Bhutan Police who own and operate radio networks.<br>Sectors own and operate data systems related to their mandates. E.g. DLGDM owns and operates DMIS, MHRDSS etc.<br>The Bhutan Broadcasting Service Corporation is the only television broadcast media company in Bhutan. |

| | |
|---|---|
| **POLICY** | Bhutan Telecommunications and Broadband Policy 2014 covers both telecommunication and broadband infrastructure and services. The policy provides a set of policy elements to guide the sector including, among others, greening of infrastructure construction, universal access, quality of service, consumer protection and safety, and sharing of infrastructure. It also requires the setting up of institutions and a regulatory framework. Section 2.13 of the policy element particularly addresses the need for disaster communication and the roles of the relevant agencies to leverage disaster-resilient telecom and ICT infrastructure, emergency communication systems and contingency planning based on international best practices. Strategic goal 16 requires the relevant agency to set up hotlines and draft a business continuity plan.<br>The Information, Communication and Media Act 2018 provides for clarity in the roles and responsibilities of implementing and regulatory bodies for effective alignment and progress. It establishes the Bhutan Infocom and Media Authority (BICMA) as the regulatory body to implement the act. It provides for the ICT sector's role in disaster risk reduction and redundancy measures including leveraging telecommunication and ICT infrastructure and media services to prevent, mitigate and manage disasters, establishing disaster-resilient communication systems, and hotlines for emergency services.<br>The revised Bhutan ICT Roadmap 2011 is a set of strategies to meet the objectives of ICT for good governance, national shared consciousness including equal access and environmental protection, and ICT as a key enabler for sustainable economic development. |

# ICT Sector Vulnerabilities

**Despite the remarkable progress made in digital transformation, Bhutan still faces challenges that hinder its digital success.** The stress test analysis identified cybersecurity breaches as the most significant threat, accompanied by a lack of expertise in maintaining cybersecurity. In terms of exposure, earthquakes and landslides pose the highest risks to ICT infrastructure.

The stress test also identified a high dependency on electricity generation, transmission, and distribution. Additionally, there is a medium dependency on water supply, wastewater management, and transport services. On the other hand, with the growing focus on ICT for development, maintaining key functions such as internet access, routing, and connectivity remains crucial across major sectors. Air transport and healthcare services are shown to be highly reliant on access to internet services. Water supply and distribution, surface transport services, electricity generation, transmission and distribution, as well as education services are increasingly dependent on internet access. Generally, public administration and financial services exhibit high dependencies on ICT for daily operations, online services, and financial transactions.

*Table 24. Internet routing, access & connection dependencies to other critical functions with ationale.*

| HIGH | MEDIUM |
|---|---|
| **Generate and transmit electricity** *(Any interruption in power supply can lead to significant outages in ICT in general and internet in particular, highlighting the need for power supply redundancies)* | **Supply water and wastewater management** *(Mainly related to maintaining sanitary conditions in facilities that house internet infrastructure, such as data centres and offices of internet service providers)*<br><br>**Transport cargo and passengers by road and air** *(Vital for the logistics of maintaining and expanding internet infrastructure including delivery of hardware such as servers, routers, and cables, as well as the transportation of personnel needed for installation, maintenance, and emergency repairs)*<br><br>**Build and maintain bridges and tunnels** *(Same as above)*<br><br>**Build and maintain health care facilities** *(Related to workforce wellbeing & productivity, occupational health & safety, disease prevention & control* |

# Current Resilience Measures

The Government has established the Bhutan Computer Incident Response Team (BtCIRT) as a central point of contact for all cybersecurity matters related to national security in the country. BtCIRT is tasked with establishing the necessary policies and procedures to effectively implement its functions as outlined in the relevant Act. Additionally, a national task force on cybersecurity has been formed to address these issues comprehensively. To enhance preparedness, cybersecurity incident simulation exercises are regularly conducted.

# Gaps and Implementation Plan

*Table 25. ICT sector Implementation Plan*

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY/ TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| There is insufficient targeted training and education for employees on environmental safety, risk prevention, and specific exposure risks based on risk analysis. | **Enhance the capacity of employees on environmental safety and risk analysis and prevention.**<br><br>Type:<br>Capacity Building | • Provide training and awareness to targeted employees on Environmental safety, Risk prevention, and specific exposure risks based on risk analysis. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Short Term – 6 months | **Lead:**<br>**GovTech Agency**<br><br>Support:<br>BICMA<br>ICT firms |
| Lack of a cyber resilience framework that includes a unified vision and collaboration among stakeholders; cyber initiatives remain fragmented. | **Establish a cyber resilience framework and expertise.**<br><br>Type:<br>Coordination and Capacity Building | • Draft/finalize the cybersecurity strategy in coordination with stakeholders. | **Proactively Protected** | **High**<br><br>Timeframe:<br>Short Term – 6 months | **Lead:**<br>**GovTech Agency**<br><br>Support:<br>BICMA, Telecos, ISPs |
| | | • Provide cybersecurity training to targeted employees. | **Proactively Protected** | **High**<br><br>Timeframe:<br>Medium-term | **Lead:**<br>**GovTech Agency**<br><br>Support:<br>BICMA<br>ICT firms |
| While obligations for environmental-impact assessments are in place, they are not consistently enforced, and sustainable procurement practices are only partially implemented, leading to potential environmental risks and missed opportunities for promoting sustainability in ICT infrastructure projects. E.g. there is a lack of monitoring systems and documentation of e-waste including a lack of acute hazardous waste management such as disposal sites. | **Strengthen environmental compliance by establishing monitoring and compliance mechanisms to assess and enhance monitoring capacity regularly**<br><br>Type:<br>Monitoring and Infrastructure Development Project | • Develop clear guidelines and SOPs for regular audits and inspections of hazardous e-waste.<br><br>• Establish monitoring and compliance capacity.<br><br>• Conduct regular monitoring. | **Environmentally Integrated** | **Medium**<br><br>Timeframe:<br>Medium Term – 1-2 years | **Lead:**<br>**DECC and DOW**<br><br>Support:<br>GovTech, BICMA, Telcos. ISPs, Private ICT sectors |
| | | • Identify and designate acute hazardous waste infrastructure (disposal sites & treatment facilities). | **Environmentally Integrated** | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**GovTech Agency, ISP**<br><br>Support:<br>NLC, DLGDM, LG |
| There are limited investments in emergency management plans, which hinders preparedness and response capabilities. Investments for maintenance and preventative maintenance programmes, and considerations for long-term, lifecycle-based investments are also limited. | **Improve emergency management plans through targeted investment plans and capabilities**<br><br>Type:<br>Capacity Building (Finance) | • Draft strategic investment plans that integrate funding for emergency management, maintenance, and long-term infrastructure upgrades, prioritizing regular reviews and updates to adapt to evolving infrastructure needs and emerging risks. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Long Term – 3-5 years | **Lead:**<br>**DLGDM, GovTech, BPC, Telecos**<br><br>Support:<br>MOF |

# E. EDUCATION SECTOR

**The education system in Bhutan is composed of school education (ECCD, schools, tertiary), monastic education, vocational, and non-formal education.** There are 1,896 schools and institutions, 12,221 teachers and faculty, and a student body of 196,441. Although education is centrally coordinated, its implementation is largely decentralized to the local government level to allow for greater autonomy, accountability and dynamism. Dzongkhag and gewog (sub-districts) administrations are entrusted with a range of education sector responsibilities including formal and non-formal education, school construction and maintenance, supply of learning and teaching materials, deployment of teachers across the dzongkhags, and implementation of national education policies.

*Image by Pradip Kar from Pixabay*

# Education Sector Institutions and Policy Framework

*Table 26. Education sector actors and policy framework.*

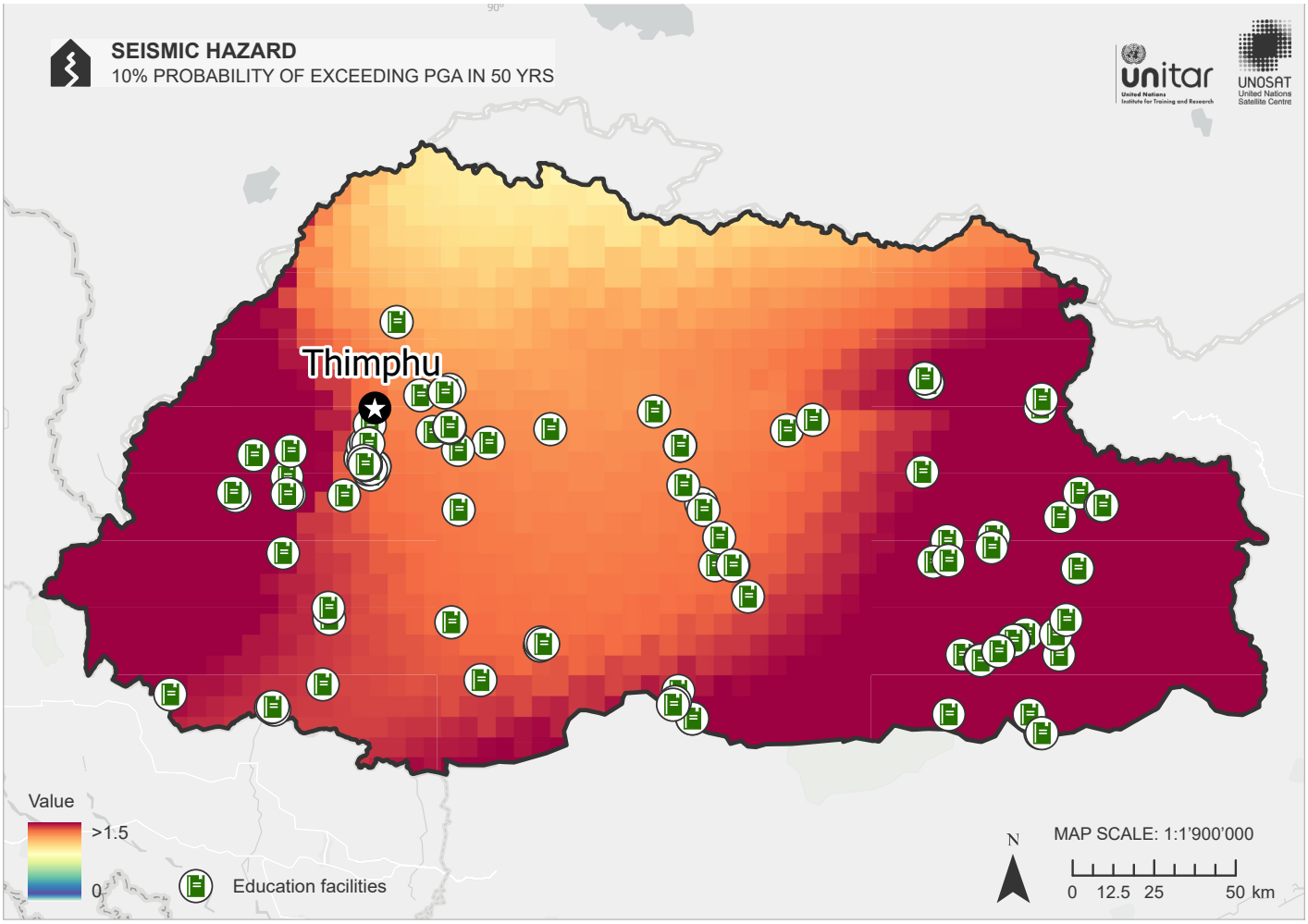
| EDUCATION | |
|---|---|
| **POLICYMAKERS** | Ministry of Education and Skills Development (MoESD)<br>The Ministry of Education provides the overall policy guidelines for the development of school education in the country. Further, it facilitates the effective coordination and collaboration between the Ministry, other agencies, local governments and schools for the development and implementation of educational policies, plans and services. The Ministry also regularly reviews its internal structure and mandates in order to enhance its efficiency and service delivery.<br>Royal University of Bhutan provides tertiary education policies while the Zhung Dratsang provides monastic institution policies. |
| **REGULATORS** | Ministry of Education and Skills Development regulates school activities |
| **OWNERS** | The Dzongkhag and Thromde are responsible for school infrastructure, assets, plans and programmes.<br>Private School Operators are owners of school planning, infrastructure and assets.<br>The Zhung Dratsang owns the monastic institutes. |
| **OPERATORS** | The Dzongkhag and Thromde offices are required to support and facilitate coordination, collaboration, and implementation of educational plans, programmes, and services at the dzongkhag and thromde level. These responsibilities include school construction and maintenance, supply of teaching and learning materials, deployment of teachers within the dzongkhag/thromde, and implementation of national policies.<br>Private school owners are operators.<br>The Zhung Dratsang operates the monastic institutions. |
| **POLICY** | The draft Education Policy 2019 emphasizes the importance of developing and maintaining safe, accessible, and inclusive educational environments. It mandates that all schools must have standard physical facilities, including classrooms, functioning water and sanitation systems, and other essential infrastructure that ensures safety and effective learning. Moreover, the policy requires that schools have eco-friendly infrastructure designed with consideration for Bhutanese architectural styles and climate conditions. Additionally, the policy includes provisions for disaster management and preparedness. |

# Education Sector Vulnerabilities

**The education sector policies are at a nascent stage, with a draft education policy drafted in recent years**. Financial constraints limit the ability to expand or improve infrastructure and facilities. Many schools lack basic infrastructure, such as science laboratories, computer labs, and internet connectivity, which hinders the implementation of modern curricula and ICT-based teaching. Limited access to specialized institutions for students with disabilities, especially at the middle and higher secondary levels, challenges inclusivity.

Figure 8 shows the Global Earthquake Model (GEM)[8] Global Seismic Hazard data for Bhutan. The GEM depicts the geographic distribution with a 10% probability of exceeding PGA in 50 years, computed for reference rock conditions (shear wave velocity, Vs30, of 760-800 m/s). There are 166 education facilities in the country, all exposed to potential high seismic hazards, being located in areas with 0.20 to >1.5 g.

*Figure 8. Education sector assets exposed to seismic hazard. Source: Global quake model platform and DLGDM.*




8. Global Earthqueake Model, https://www.globalquakemodel.org/product/global-seismic-hazard-map#:~:text=The%20Global%20Earthquake%20Model%20(GEM)%20Global%20Seismic%20Hazard

**The stress test analyses have identified school systems—both infrastructure and occupants—as highly vulnerable to earthquakes, landslides, structural fires, and epidemics, with flooding posing a medium risk.** Historical loss and damage data also highlight the vulnerability of school infrastructure to multiple hazards. For instance, the September 2011 M6.8 Sikkim earthquake damaged 36 schools, resulting in an estimated loss of USD 1.1 million. Similarly, the September 2009 M6.1 earthquake in Eastern Bhutan damaged 117 schools, with reconstruction costs estimated at USD 13.49 million.

Windstorms have become a recurrent hazard affecting schools in recent years. Between 2011 and 2015, over 100 schools and Early Childhood Care and Development (ECCD) centres across various Dzongkhags reported damage caused by windstorms. Bhutan is also susceptible to seasonal flash floods, landslides, and Glacial Lake Outburst Floods which have previously resulted in damage to school buildings and loss of lives. In the Punatsangchu river basin, four schools and two vocational training institutes were identified among the 21 vulnerable communities located within the GLOF red zone hazard map. These risks underscore the critical need for enhanced disaster preparedness and resilience within the education sector.[9]

With a current population of 12,221 teachers and faculty, and a student body of 196,441, across 1,896 schools and institutions at any one point in time, a substantial portion of the population is exposed to these hazards, underscoring the potential for widespread disruptions, damage and loss.

The vulnerability assessment carried out for the education sector disaster management plan reported that community-built and non-engineered school buildings are extremely vulnerable to hazards such as earthquakes and windstorms. This infrastructure also suffers from poor electrification and inadequate maintenance, further exacerbating their susceptibility to natural hazards. Meanwhile, remote rural schools face additional risks due to limited accessibility and communication facilities[10].

The effective functioning of the education sector would be severely compromised without efficient water supply, electricity, road and surface transport functions. It is also dependent on wastewater management and access to ICT and health services. This reliance on essential infrastructure means that any disruption in these areas could significantly impair education activities. As a result, it is important for the education sector to account for potential cascading impacts when conducting vulnerability assessments, ensuring a comprehensive understanding of the risks posed by interruptions in these critical services.

*Table 27. Build & maintain school functions & dependencies.*

| HIGH | MEDIUM |
|---|---|
| **Supply, treat and distribute water** *(Constant and reliable supply of clean water for drinking, sanitation, and maintaining hygiene standards)* | **Manage wastewater** |
| **Transport cargo and passengers by road** *(Education continuity with daily operation of schools, facilitating the movement of students, staff, and supplies)* | **Transport cargo and passengers by air** *(emergency purposes)* |
| **Build and maintain bridges and tunnels** *(same as above)* | **Provide Internet Routing, Access, and Connection** *(Reliable internet connectivity is essential for ensuring that students and staff can access digital resources, participate in virtual learning environments, and communicate effectively)* |
| **Generate and Transmit electricity** *(Vital for the operation of schools, powering lights, heating and cooling systems, educational technology, and communication devices)* | **Build and maintain health care facilities** |

9. Jean-Joseph Bellamy and Yeshey Penjor, 2014, Terminal Evaluation Report "Reduction Climate Change-Induced Risks and Vulnerabilities from Glacial Lake Outburst Floods in the Punakha, Wangdue and Chamkhar Valleys (GLOF)".
10. Minsitry of Education (2016), Education Sector DMCP 2016

# Current Resilience Measures

The Disaster Management Unit, under the School Planning and Coordination Division within the Department of School Education (DSE), Ministry of Education and Skills Development, serves as the focal agency for disaster management in the education sector. The DSE plays a pivotal role in aligning national disaster management policies and plans with educational needs, including the endorsement of the National Action Plan for School Earthquake Safety.

**Awareness and capacity-building initiatives have been carried out** since 2010 under the Safe School Initiatives. All schools in Bhutan now have School Disaster Management and Contingency Plans in place. The implementation of these plans is monitored through the School Performance Monitoring System. The MoESD has drafted a comprehensive education sector Disaster Management and Contingency Plan to ensure the safety of students and staff, and to maintain educational continuity during disasters. The plan includes a multi-level framework that addresses risk reduction, resilience-building, and preparedness. It establishes coordination mechanisms between national, dzongkhag, and school-level institutions, outlining clear roles and responsibilities. Priorities include strengthening institutional frameworks, enhancing disaster awareness, improving risk reduction and mitigation measures, and building capacities across all levels.

The School Planning and Building Division (SPBD) of MoESD had incorporated disaster-resilient features into new school building designs. Vulnerability assessments of existing school structures, particularly non-engineered community-built structures, have been carried out using a checklist, with engineers trained to assess schools in at least eight Dzongkhags.

# Gaps and Implementation Plan

*Table 28. Education sector Implementation Plan*

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY/ TIMERAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| Poor structural resilience:<br>There is limited and/ or sporadic monitoring and insufficient stress testing that lacks comprehensive hazard considerations leading to a lack of structural maintenance of school buildings. | **Establish a monitoring system that tracks the condition of school infrastructure and identifies potential hazards in real time.**<br><br>Type:<br>Monitoring, Infrastructure project/Retrofits, and Capacity Building | • Draft monitoring protocol (SOP) for school infrastructure. | **Continuously Learning** | **High**<br><br>Timeframe:<br>Short Term – By December 2025 | **Lead:**<br>**DSE, MoESD**<br><br>Support:<br>DLGDM, MOIT, Local Government, UNICEF, Save the Children, NLCS |
| | | • Conduct periodic monitoring & stress tests and scenario analyses that consider a wide range of hazards, including disasters and structural failures, guided by national standards and building codes. | **Continuously Learning** | **High**<br><br>Timeframe:<br>Long Term | **Lead:**<br>**MoESD, DoID** |
| | | • Develop geospatial mapping for education infrastructures in the country. | **Continuously Learning** | **High**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**MoESD, DoID** |
| | | • Plan for risk-informed investments to remodel, restructure and retrofit existing structures. | **Continuously Learning** | **High**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**MoESD, DoID** |
| There is insufficient capacity and coverage for preparedness and response. | **Build capacity in disaster preparedness and response for principals, focal teachers and the schools.**<br><br>Type:<br>Capacity Building | • Conduct regular training and workshops for disaster focal teachers and dzongkhag education officers for effective coordination.<br><br>• Appoint disaster focal teachers and conduct training in ECCDs and special needs schools. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Long Term (Continous) | **Lead:**<br>**DSE, MoESD**<br><br>Support:<br>DLGDM, UNICEF, Save the Children |

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY/ TIMERAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| There are inadequate measures to enhance the physical safety of existing schools and insufficient adherence to risk assessments for new school construction. | **Enhance the physical safety of school infrastructure in existing DM activities.**<br><br>Type:<br>Monitoring | • Implement DMCP in a phased manner in the education sector.<br>• Ensure no school is built in hazard-prone areas (flood and landside).<br>• Ensure new schools are built based on disaster-resilient design concepts. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Long Term | **Lead:**<br>**DSE, MoESD**<br><br>Support:<br>NLCS, MOIT |
| Risk reporting is limited covering a narrow scope of disaster (mainly non-structural via DM Plans), limiting opportunities for comprehensive risk-informed investment and improvement in infrastructure resilience. | **Enhance the scope of risk reporting to include both structural and non-structural risks.**<br><br>Type:<br>Policy and Regulation | • Update or draft standardized and mandatory reporting guidelines and frameworks that include structural and non-structural assessments. | **Shared Responsibily** | **Medium**<br><br>Timeframe:<br>Medium Term – 2025-2026 | **Lead:**<br>**DSE, MoESD**<br><br>Support:<br>DLGDM, MOIT, UNICEF, Save the Children (Support) |
| The current disaster management plan of Education is not inclusive and does not cover all potential scenarios or is not sufficiently detailed. | **Assess and integrate comprehensive risk scenarios in education sector DRM plans.**<br><br>Type:<br>Coordination and Data Assessment | • Update the DMCP with sufficient DRR elements (structural & non-structural), a detailed and scenario-specific disaster management plan that includes risk assessment, mitigation strategies, and response protocols (natural hazards, pandemics, etc.). | **Adaptively Learning** | **Medium**<br><br>Timeframe:<br>Short Term – 2025-2026 | **Lead:**<br>**DoSE, MoESD**<br><br>Support:<br>DLGDM, MOIT, UNICEF, Save the Children |

# F. HEALTH SECTOR

The case for health sector resilience is evident, especially in the wake of the global disruptions caused by the COVID-19 pandemic, which underscored the vulnerabilities in health systems in Bhutan. Public health programmes and health services in Bhutan are free as provided by the Constitution, and the health system is predominantly financed and managed by the public sector. Health services are delivered through a three-tier structure: primary, secondary, and tertiary levels. Traditional and allopathic medicine are integrated and provided through three referral hospitals, 28 district hospitals including one indigenous hospital, 207 Basic Health Units, 28 sub-posts, 562 ORCs and 54 indigenous units. There are 3.5 health facilities per 10,000 population[11].

## Health Sector Institutions and Policy Framework

*Table 29. Actors and policy framework*

| HEALTH SECTOR | |
|---|---|
| **POLICYMAKERS** | Ministry of Health<br>The ministry is responsible for formulating health policies, designing programmes, and issuing technical guidelines and directives for all health-related initiatives. It is also responsible for drafting health legislation, ensuring compliance with national and international regulations, and maintains a regulatory system to safeguard the quality, safety, equity, and efficiency of health services across the country. |
| **REGULATORS** | While the ministry regulates the health system, Bhutan is obligated under the International Health Regulations (IHR 2005) to prevent and respond to the global spread of diseases. It requires Bhutan to enhance surveillance, reporting and health measures. |
| **OWNERS** | All levels of health systems are owned and operated by Ministry of Health. |

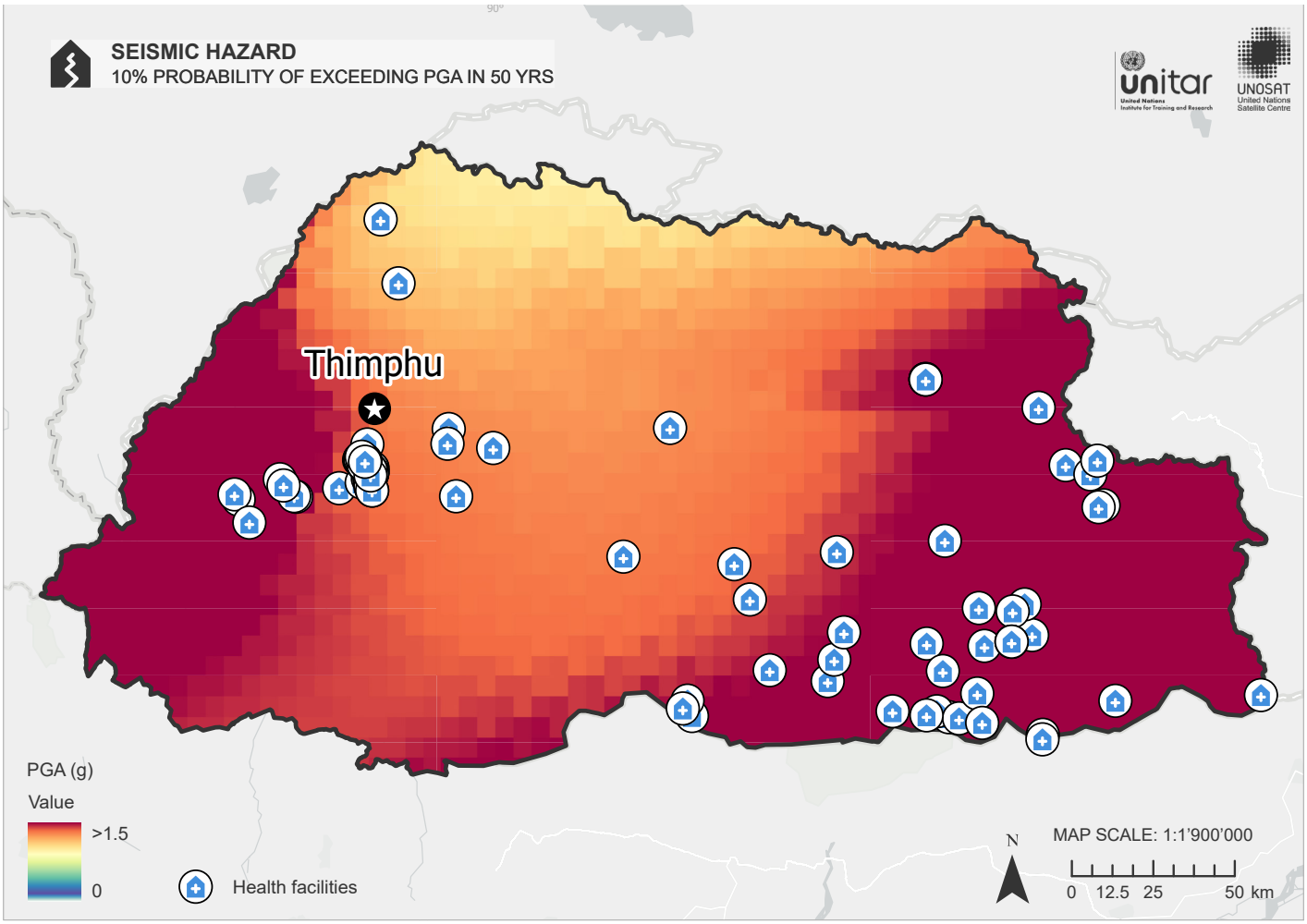
11. *Ministry of Health 2017, The Kingdom of Bhutan health system review, 2017*

| | |
|---|---|
| **OPERATORS** | All levels of health systems are owned and operated by Ministry of Health. |
| **POLICY** | The National Health Policy of Bhutan aims to ensure universal access to quality health services, integrating modern and traditional medicine, and maintaining health infrastructure. The policy focuses on disease prevention, health promotion, and community participation, besides establishing a comprehensive health information system. It also includes provisions for emergency preparedness, response mechanisms for health-related crises, and maintaining high standards in health service delivery through continuous monitoring and quality improvement initiatives. |

# Health Sector Vulnerabilities

Despite significant health milestones, Bhutan continues to grapple with several challenges. From a disaster risk perspective, the stress test analysis revealed that healthcare facilities are highly vulnerable to earthquakes, fires, landslides, and epidemics. Figure 9 depicts a susceptibility map showing health infrastructure assets including hospital, clinics, basic health care units and pharmacies located across the country. UNOSAT's analysis of the data showed 149 health facilities in the country, all exposed to potential high seismic hazards being located in areas with over potential 0.20 g PGA. In addition, there are persistent communicable diseases, increasing incidences of non-communicable diseases, and the re-emergence of zoonotic diseases, all exacerbated by geo-climatological hazards driven by climate change. Significant health equity disparities, with variable access to health services, utilisation rates, and health outcomes between urban and rural areas, different income levels, and regions exist (WHO 2024).

*Figure 9. Health Sector assets exposed to seismic hazard. Source: Global quake model platform and DLGDM.*



The stress test analysis highlights heavy reliance of the health services on other critical infrastructure and services including water supply, treatment and distribution, electricity transmission, ICT services, and transportation of cargo and passengers by air and road. This reliance underscores the need for a resilient and well-integrated support system to ensure continuous and effective healthcare services.

Table 30. Build and maintain health facilities: dependency & rationale.

| HIGH | MEDIUM |
|---|---|
| **Supply, treat and distribute water** *(Access to clean and treated water is fundamental to healthcare operations and essential functions, including patient care, sanitation, medical procedures, sterilization of equipment, and maintaining overall hygiene. Any disruption in water supply can severely impact healthcare services, leading to potential health risks and compromised care)*<br><br>**Manage wastewater** *(Proper wastewater management is critical in healthcare to prevent the spread of infectious diseases. Healthcare facilities generate a significant amount of hazardous biological and chemical waste, which must be managed effectively to avoid contamination and environmental hazards)*<br><br>**Transport cargo and passengers by road and air** *(Road & air transport are essential for the timely movement of patients, medical staff, and critical supplies. Emergency services rely on road transport to provide emergency care)*<br><br>**Build and maintain bridges and tunnels** *(same as above)*<br><br>**Generate & transmit electricity** *(Reliable power supply is indispensable in healthcare facilities, powering critical medical equipment, lighting, heating and cooling systems, and communication networks, highlighting the need for power supply redundancy measures)*<br><br>**Provide internet routing, access, and connection** (Increasingly relevant for emergency communication, operation and management, telemedicine, research, accessing and enabling remote consultations) | **Build and maintain schools facilities** |

# Current Resilience Measures

The National Health Policy underscores the continuation of a comprehensive approach to primary health care, ensuring universal access. Bhutan continues to invest in health infrastructure and services to support this commitment.

To sustain primary health care, the Bhutan Health Trust Fund was established. The Health Emergency and Disaster Contingency Plan (HEDCP) has been drafted to ensure Bhutan's health sector is well prepared and can respond to emergencies. It outlines procedures for health responses, management of resources, coordination, and communication, serving as a guiding document for health and humanitarian interventions before, during, and after emergencies.

Besides priority health security and disease outcomes, the health sector's 13th FYP focuses on innovation in governance, sustainable health financing systems and ICT to enhance health system efficiency.

The Medical and Health Professionals Council under Bhutan Qualifications and Professional Certification Authority was established to strengthen public health safety through effective enforcement of policies, regulations and standards. It is a member of the Medical Councils Network of the WHO South-East Asia Region and the International Association of Medical Regulatory Authorities.

# Gaps and Implementation Plan

*Table 31. Health sector Implementation Plan*

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY/ TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| Limited maintenance budgets and preventative maintenance investment for health infrastructure, including rehabilitation or refurbishing. | **Enhance health infrastructure resilience through monitoring, stress testing, and maintenance planning.**<br><br>Type:<br>Coordination, Governance and Policy | • Carry out monitoring and stress testing of health infrastructures using multi-hazard assessment criteria.<br>• Conduct comprehensive vulnerability assessments of major health facilities.<br>• Update geospatial mapping/database for health infrastructure in the country.<br>• Draft and implement a systematic maintenance plan that prioritizes maintenance and rehabilitation. The plan should include regular inspections, risk assessments, and condition monitoring to identify maintenance needs before they become critical. | **Proactively Protected** | **High**<br><br>Timeframe:<br>Short Term – By December 2025 | **Lead:**<br>**Department of Clinical Services, NMS & Health Emergencies Programme, DoPH, MOH**<br><br>Support:<br>DLGDM, MOIT, WHO, UNOSAT, UNDRR, GHI, CDRI |
| | | • Advocate for and establish dedicated funding for maintenance and rehabilitation activities such as fixing a percentage of the health infrastructure budget for ongoing maintenance and future refurbishment needs. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**MoH**<br><br>Support:<br>LG, MoF, WHO, DOID, DLGDM |

| GAP/FINDING | RECOMMENDATION | ACTIVITY | PRINCIPLE | PRIORITY/ TIMEFRAME | RESPONSIBLE AGENCY AND POTENTIAL PARTNER |
|---|---|---|---|---|---|
| Insufficient communication networks to facilitate redundancies during emergency communication. | **Strengthen communication networks, ensuring that health facilities have reliable alternative communication tools to stay connected during emergencies.**<br><br>Type:<br>Coordination and Capacity Building | • Develop a communication plan during emergencies aligning with the National Disaster Management Plan.<br><br>• Procure communication equipment and distribute it to health facilities. | **Shared Responsibility** | **Medium**<br><br>Timeframe:<br>Short Term | **Lead:**<br>**DCS, NMS & HEP DoPH, MOH**<br><br>Support:<br>DLGDM, GovTech, Bhutan Telecom, BICMA, WHO |
| | **Establish a pool of mobile Emergency Medical Technicians (EMTs) trained to respond quickly to emergencies and assist overwhelmed local healthcare facilities. Establish formal agreements with neighbouring countries or INGOs to support emergency response.**<br><br>Type:<br>Coordination | • Develop SOPs for Emergency Medical Technicians.<br><br>• Form Emergency medical teams at the national and District levels.<br><br>• Develop SOPs for requesting external aid for emergency medical assistance. | **Shared Responsibility** | **High**<br><br>Timeframe:<br>Short Term | **Lead:**<br>**DCS, NMS & HEP DoPH, MOH**<br><br>Support:<br>DLGDM, MoFAET, WHO |
| Structural resilience of health infrastructures is weak. | **Health Infrastructure Climate Resilience Upgrade (Implement and ensure compliance).**<br><br>Type:<br>Infrastructure Project/ Retrofit | • Upgrade existing health facilities with climate-smart and disaster-resilient designs.<br><br>• Mandate that all newly constructed health facilities meet standards for climate resilience, accessibility for people with disabilities, and energy efficiency. | **Environmentally Integrated** | **Medium**<br><br>Timeframe:<br>Long Term – By end of 13 FYP | **Lead:**<br>**MoH**<br><br>Support:<br>RAA, DECC |
| There are insufficient strategically located emergency stockpiles, leaving healthcare services vulnerable during crises. The transportation infrastructure supporting health facilities is also insufficient, particularly in remote and hard-to-reach areas. | **Establish strategic stockpiles of critical medicines, PPE, and emergency equipment in key regions of the country to ensure continued healthcare services during crises.**<br><br>Type:<br>Capacity Building | • Establish strategic stockpiles of critical medicines, PPE, and emergency equipment in key regions (Phuentsholing & Gelephu). | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**Department of Medical Product, NMS, MoH**<br><br>Support:<br>MoF, WHO, UNICEF, WFP |
| | **Improve transportation infrastructure for health facilities, ensuring better access to remote areas and building redundancy into supply chains for quicker recovery after disasters.**<br><br>Type:<br>Capacity Building | • Develop a transportation plan for the supply chain during disasters. | **Proactively Protected** | **Medium**<br><br>Timeframe:<br>Medium Term | **Lead:**<br>**Department of Medical Product, NMS, MoH**<br><br>Support:<br>MoF, WHO, UNICEF, |

# PRIORITY ACTIONS AND NEXT STEPS

Based on the analysis and the recommendations, stakeholders from the key sectors across the government, the state-owned enterprises and the private sector, worked together to identify priority recommendations to improve synergies and coordination for enhancing infrastructure resilience. The recommendations are prioritized based on national resilience objectives and specific sectoral needs that align with sector priorities outlined in the Five Year Plan. A significant outcome of this assessment is the agreement among sectors to incorporate the recommendations into their action plan as part of their Five Year Plan. Below are top priority recommendations for implementation and the next steps.

*Table 32. Priority actions by Sector*

| SECTOR | PRIORITY RECOMMENDATION | PRIORITY ACTIVITIES |
|---|---|---|
| CROSS SECTOR | Integrate critical infrastructure multi-hazard risk assessments, stress testing and resilience measures across sectors. | Multi-sector assessments and stress testing in sectors, developing guidelines and criteria. |
| | Enhance critical infrastructure resilience governance through coordinated mechanisms and commitments. | Identify and map critical infrastructure sectors and assets. |
| | Enhance data sharing across infrastructure sectors to improve cross-sectoral collaboration for infrastructure planning and decision-making. | Create a task for critical infrastructure. |
| | | Data sharing guideline/framework that ensures trust, data security, as well as access to information/data for all sectors. |
| TRANSPORT | Infrastructure design & upgrades: using new technologies, stronger materials, elevated structures, permeable pavements. | Collaborate with private firms on new technologies in the market. |
| | | Update design standards based on the upgraded construction materials. |
| ENERGY | Enhance compliance with safety standards of BPC/BSB by standardizing and establishing mechanisms to ensure safety code alignment. | Update BPC's safety codes & SOPs. |
| | | Train and build capacity on safety codes and SOPs, safety awareness campaigns. |
| | | Conduct regular monitoring and audits to improve compliance. |
| WATER | Enhance the capacity of local governments in water and wastewater management. | Draft guidelines for local government water managers and support their implementation. |
| | | Capacity building for local government, water treatment plant operators and others for O&M |
| ICT | Establish cyber resilience framework and expertise. | Draft cybersecurity strategy in coordination with stakeholders. |
| | | Carry out cybersecurity capacity building and training. |

| SECTOR | PRIORITY RECOMMENDATION | PRIORITY ACTIVITIES |
|---|---|---|
| **HEALTH** | Establish & train a pool of mobile EMTs to respond quickly to emergencies. Establish formal agreements with neighbouring countries or INGOs to support emergency response. | Develop SOP for emergency medical teams and train |
| | | Develop SOP for requesting external aid for emergency medical teams. |
| **EDUCATION** | Establish a monitoring system that tracks the condition of school infrastructure and identifies potential hazards in real-time. | Draft monitoring protocol (SoP) for school infrastructure. |
| | | Conduct periodic monitoring & stress tests and scenario analyses that consider a wide range of hazards, including natural hazards and structural failures, guided by national standards and building codes. |
| | | Develop geospatial mapping for education infrastructure in the country.<br><br>Plan for risk-informed investments to remodel, restructure and retrofit existing structures. |

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## ANNEX I: CROSS SECTOR POLICY AND REGULATORY REVIEW

| DOCUMENT TITLE | LINK TO THE PRINCIPLES | | | | | |
|---|---|---|---|---|---|---|
| | P1 | P2 | P3 | P4 | P5 | P6 |
| | Does the document call for multi-hazard assessment, including requirements for stress testing and for using this information for formulating improvements in the sector? | Does the document raise safety requirements, promote regular safety updates, and/or call for backup systems in case of disruption in the sector? | Does the document aim at minimising environmental impact and encourage the use of environmental solutions to deliver infrastructure services in the sector? | Does the document foster communication among operators in the sector and engagement with users, for example for demand management purposes? | Does the document clarify the roles and responsibilities of each actor in the sector, require intra/ inter-sectoral collaboration and facilitate the sharing of information? | Does the document require the sector operators to have plans and strategies for adapting to changing needs? |
| DISASTER MANAGEMENT ACT 2013 | The Act provides for multi-hazard risk assessments but does not provide for stress testing of critical infrastructures. | It calls for the establishment of critical Disaster Management facilities and regular updates on disaster management measures, as stated in Clause 56(c-f). | Clause 12, defines DRR as the conceptual framework aimed at minimizing disaster risks and promoting sustainable development practices although environmental impacts are not specifically mentioned | The Act fosters communication and coordination between agencies, the private sector, and the public, especially in Clause 60(g) and Clause 108, which emphasize information sharing and early warning systems. | The Act is clear on roles and responsibilities. | It mandates that every agency& private sector must prepare a DM plan to be reviewed and updated to ensure adaptability to evolving circumstances. |
| NATIONAL DM STRATEGY 2017 | The strategy emphasizes the importance of understanding disaster risks through hazard mapping and risk identification, but it does not explicitly mention stress testing. | It recognizes the need for strengthening disaster management capabilities, including the establishment of EWS and critical infrastructure resilience. There is no explicit reference to redundancies and backup systems. | It is intrinsically captured in the reference to sustainable development although the document does not contain specific requirements for adherence to environmental mandates. | The NDRM has a strong emphasis on the importance of communication and coordination among various stakeholders, including local communities, for effective disaster management. | The document clearly outlines the roles and responsibilities of different agencies and stakeholders, promoting a multi-sectoral approach to disaster risk reduction and management. | The NDRMS requires sector operators to integrate disaster risk management and adaptation strategies into their plans, particularly within the context of sustainable development. |
| NATIONAL ADAPTATION PLAN 2023 | NAP discusses the need for better coordination to avoid maladaptation in the context of climate hazards like flash floods and landslides, implying a form of multi-hazard assessment, though explicit stress testing is not detailed (Section 4.1.3). | The NAP calls for periodic reviews and upgrades of infrastructure and the use of early warning systems to ensure safety and preparedness against disasters (Strategic Action 4 under disaster management). | It promotes leveraging green infrastructure and ecosystem-based adaptation to minimize environmental impact, particularly in urban areas (Strategic Objective 1). | The NAP emphasizes the importance of communication and outreach, particularly through platforms for policy dialogues involving stakeholders like civil society and the private sector, to ensure effective demand management (Section 4.4). | Roles and responsibilities are clearly outlined for agencies, and the document stresses intra/ inter-sectoral collaboration to ensure coherence in climate adaptation efforts (Section 4.5). | Sectoral plans for adaptation to changing climatic conditions, focusing on enhancing resilience through long-term strategies. |
| CLIMATE CHANGE POLICY | The policy does not explicitly call for multi-hazard assessments but emphasizes the importance of integrating resilience and adaptation strategies for climate risks across sectors. | Safety standards for critical infrastructures are not specifically provided. | Environmental components are inherent in the recognition of international and national legislative compliance and obligations. | It promotes synergies among sectors to avoid duplication and foster active collaboration and guidance for climate action. | Roles and responsibilities are clearly delineated with policy objective 4 providing for coordinated actions. | The implementing procedure provides for procedures to implement the policy covering agencies, institutions, organisations and stakeholder groups. |

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| COMPREHENSIVE DEVELOPMENT PLAN | The CNDP does emphasize the importance of creating resilient national spatial structures against disasters (Chapter 3.3.6), but there is no reference to specific multi-hazard assessments or stress testing | The plan calls for enhancing self-reliability in towns and villages through safety measures, including disaster response hubs and emergency training | The plan strongly advocates for eco-friendly and green industries, emphasising the use of renewable resources and green technologies for infrastructure development (Chapter 3.3.6). | There is no reference on communication among operators specific to sectors or across sectors | The plan clearly defines roles and responsibilities for local governments, ministries, and other stakeholders, while advocating for intra-sector and inter-sectoral collaboration. | The plan for promoting adaptive planning and sustainable development strategies includes periodic reviews, the promotion of resilient infrastructure, and the integration of ecosystem-based adaptation solutions. |
| COMPANIES ACT OF BHUTAN 2016 | The act does not provide for multi-hazard assessments and stress testing or using this information for sector improvements. | It does not refer to safety requirements, promote regular safety updates, or call for backup systems in case of disruption in the relevant sector. | Although the environmental concerns are covered under environmental regulations, regulatory authorities and monitoring, the act is silent on adherence to environmental regulations. | There is no direct reference to fostering communication among sector operators or engagement with users. | The document does not clarify roles and responsibilities specific to intra/inter-sectoral collaboration or information-sharing mechanisms among stakeholders. | No specific mention on plans and strategies for adaptation to changing needs etc. is provided. |
| NATIONAL CONSTRUCTION INDUSTRY POLICY | The policy does not explicitly call for multi-hazard assessments but emphasizes the need for sustainable and resilient infrastructure development, particularly in mitigating negative environmental impacts in construction projects. There is no reference to stress testing infrastructures. | The policy includes provisions for public-private partnerships and procurement procedures, but there is no specific mention of backup systems for disruptions in the sector. | The policy promotes the use of environmentally friendly solutions, including green technologies, to minimize environmental impact and deliver sustainable infrastructure services. | There is no specific mention of fostering communication among operators | The policy outlines roles for various stakeholders in public-private partnerships and sustainable development but does not detail intra/inter-sectoral collaboration or information sharing | It encourages adaptive and sustainable planning but does not elaborate on specific strategies for adapting to changing needs in the sector |
| BUILDING CODE OF BHUTAN 2018 | The code addresses earthquake resistance as a requirement, but it does not explicitly discuss multi-hazard assessments or stress testing. | It emphasizes safety requirements, particularly in the context of fire safety. | The document promotes compliance with the Bhutan Green Design Guidelines, focusing on sustainable construction. | There is no reference to communication among operators or user engagement in the context of demand management or other such requirements. | The roles of various actors are defined in terms of building permits and compliance. | The code emphasizes compliance with earthquake and fire safety standards. |
| GEO INFORMATION POLICY 2018 | The policy does not explicitly call for a multi-hazard assessment or stress testing but emphasizes the importance of using reliable geo-information for decision-making, including disaster risk management and planning. | While the policy focuses on ensuring the availability and reliability of geo-information, there is no reference to infrastructure safety requirements, regular updates, or backup systems for infrastructure disruptions. | Apart from focusing on ensuring the availability and reliability of geo-information, there is no direct mention of safety requirements, regular updates, or backup systems for infrastructure disruptions. | Environmental conservation is referenced through the optimal use of geo-information technologies, supporting informed decisions that could minimize environmental impacts | It clearly defines the roles of different agencies, including the Center for GIS Coordination (CGISC), and calls for collaboration among GI producers and users for effective management and sharing of geo-information. | The policy highlights the need for adaptive management of geo-information systems and regular updates to keep pace with technological changes and evolving national needs. |

## ANNEX II: SECTOR POLICY AND REGULATORY REVIEW

| DOCUMENT TITLE | LINK TO THE PRINCIPLES | | | | | |
|---|---|---|---|---|---|---|
| | P1 | P2 | P3 | P4 | P5 | P6 |
| | Does the document call for multi-hazard assessment, including requirements for stress testing and for using this information for formulating improvements in the sector? | Does the document raise safety requirements, promote regular safety updates, and/or call for having backup systems in case of disruption in the sector? | Does the document aim at minimizing environmental impact and encourage the use of environmental solutions to deliver infrastructure services in the sector? | Does the document foster communication among operators in the sector and engagement with users, for example for demand management purposes? | Does the document clarify the roles and responsibilities of each actor in the sector, require intra/ inter-sectoral collaboration and facilitate the sharing of information? | Does the document require the sector operators to have plans and strategies for adapting to changing needs? |
| **ENERGY SECTOR** | | | | | | |
| NATIONAL ENERGY EFFICIENCY AND CONSERVATION POLICY | The policy does not explicitly mention multi-hazard assessments or stress testing but it mandates regular energy audits, which provide systematic evaluation of energy performance. | Clause 7.1 provides for energy efficiency upgrade measures in industrial processes through retrofit, refurbishment, technology transfer etc. No other safety and redundancy requirements are mentioned. | The policy is designed to minimize environmental impact by improving energy efficiency and promoting green growth (Clause 1.4). | It provides for interactive web-based platform for disseminating best practices and other information promoting. sharing of information on energy-efficient practices | Clear roles and responsibilities of the Nodal Agency and related stakeholders, promoting coordination for policy implementation | The policy mandates updating plans every five years |
| REVISED POWER SYSTEM MASTER PLAN | There is no provision for multi-hazard risk assessments and stress testing of structural and non-structural components. | Regular inspections and safety updates are required to ensure projects are maintained to standard, with provisions for remediation and modernization where necessary. | Developers are required to conduct EIA and prepare Environmental Management Plans to mitigate adverse environmental impacts. These assessments must conform to national environmental regulations. | Emphasizes that load dispatch procedures will be regulated by the Bhutan Power System Operator (BPSO). | Clause 15.4 outlines the roles of different departments in power supply allocation and prioritization, ensuring inter-sectoral collaboration and clarity in responsibilities. | The PSMP mandates periodic updates and reviews of both the Power System Master Plan and the National Transmission Grid Master Plan to ensure relevance to evolving needs |
| NATIONAL TRANSMISSION GRID MASTER PLAN OF BHUTAN 2018 | The plan does not address multi-hazard assessments or stress testing for the grid. | Safety requirements and contingency planning are addressed, including provisions for load flow case studies and fault analysis to ensure reliability under different scenarios. | The plan makes specific reference to minimizing environmental impacts by optimizing transmission corridors to avoid national parks and biological corridors in adherence to environmental regulations. | The plan promotes coordination with cross-border partners such as India's Central Electricity Authority and Power grid for transmission planning, but does not explicitly discuss user engagement for demand management etc. | It outlines the roles of different national and international stakeholders, including the Bhutan Power Corporation, and stresses inter-sectoral collaboration for grid development and planning. | The plan includes provisions for future-proofing the transmission grid, with phased development timelines up to and beyond 2040. |

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| ELECTRICITY ACT OF BHUTAN 2001 | The Act does not explicitly mention multi-hazard assessments or stress testing. | The Act mandates the electricity authority to create safety standards, including minimum technical and safety requirements for generation, transmission, and distribution facilities. Additionally, it requires operators to comply with prescribed safety regulations. It also contains contingency provisions for backup measures during emergencies. | The act mandates that environmental considerations must be taken into account when developing the electricity supply industry. This includes ensuring that electricity projects are environmentally sustainable. | The act encourages private sector participation in electricity supply, discriminatory access to the transmission and distribution systems, and emphasizes the resolution of disputes between operators and customers. | The Act is clear on the roles and responsibilities of system operators including duties of transmission and distribution licensees. | The Act does not require the sector operators to have plans and strategies for adaptation to changing needs. |
| ALTERNATIVE RENEWABLE ENERGY POLICY | The policy does not explicitly mention multi-hazard assessments or stress testing requirements for formulating sectoral improvements. | The policy emphasizes backup support in decentralized projects (Section 7.4), but does not broadly address safety updates or backup systems beyond this context. | The policy has a strong focus on minimizing environmental impacts, with provisions for environmental assessments, promoting green energy solutions, and emphasizing renewable energy technologies as part of sustainable development. | The policy fosters communication and collaboration, particularly through project allotment processes, stakeholder involvement, and ensuring grid connection compliance, but does not explicitly mention user engagement for demand management purposes. | The roles and responsibilities of various actors are clearly defined, especially with inter-agency collaboration for renewable energy development. | The policy has a reference to promotion of alternative renewable energy technologies, future-proofing through research, and the development of infrastructure. |
| **TRANSPORT** | | | | | | |
| ROAD SECTOR MASTER PLAN (2007-2027) | There is no explicit reference to multi-hazard assessments or stress testing requirements for road infrastructure. However, detailed geotechnical assessments are carried out for major road network and infrastructure planning. | The plan includes provisions for improving safety through road realignment, tunnelling, and design upgrades but does not specifically provide for regular safety updates or backup systems. For major road networks, infrastructure parts are stockpiled for emergencies. | The plan is obligated to the environmental mandates. It specifically makes references to planning road alignments to avoid sensitive areas, such as agricultural lands and forests. | Key stakeholder collaboration (including with local governance and road agencies) for road planning are referenced. There is no provision for user engagement. | Roles and responsibilities are clarified for national agencies and local authorities. | There is a general provision for adaptive strategies for the future, such as road realignments and technology upgrades, to address the country's growing transportation needs. |
| BHUTAN TRANSPORT 2040 | Although the plan calls for improvement of infrastructure to respond to future needs, it does not require multi-hazard assessments or stress testing. | Safety measures are a key element of the plan, with a dedicated road safety strategy that includes establishing a road safety board, driver training, and vehicle testing programmes. | There is a focus on promoting green transport solutions and energy-efficient modes of transportation. | Inter sector coordination and communication are captured partially between urban planning and traffic management. It does not foster user engagement such as private sector operators. | Roles and responsibilities are defined, and the plan promotes coordination among road authorities, local governments, and the private sector. | There is a specific reference to future-proofing Bhutan's transport system by promoting sustainable practices and infrastructure development to adapt to socioeconomic changes. |

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| ROAD ACT OF THE KINGDOM OF BHUTAN 2004 | The policy does not include specific provisions for multi-hazard assessments or stress testing as a requirement for formulating improvements in the road sector. | It sets out specific technical standards for road parts (e.g., carriageways, shoulders, etc.), road alignment, and road safety. There is no provision for back up systems | It requires road agencies to conform to environmental, geological, and socio-economic considerations during construction | Collaboration between various governmental road agencies and stakeholders are addressed but it makes no reference to user engagement. | Roles and responsibilities are defined for different road agencies, including specific road agencies and local authorities to promote inter-sectoral collaboration | It does not specifically mandate operators to have strategies for adapting to changing needs |
| ROAD SAFETY AND TRANSPORT ACT OF BHUTAN 1999 | There are no provisions for multi-hazard assessments or stress testing. | It provides for safety standards, including driver licensing, vehicle registration, and the establishment of the authority to enforce regulations. | There is no explicit mention of environmental concerns or solutions within the document. | The act promotes coordination between the Road Safety and Transport Authority and other stakeholders but does not emphasize user engagement. | There is clear delineation of the roles and responsibilities of transport operators and transport authorities. | There is no specific or intrinsic reference to plans and strategies for adapting to changing needs. |
| CIVIL AVIATION ACT OF BHUTAN 2016 | The act does not provide for multi-hazard assessments or stress testing for improving aviation systems. | It addresses safety requirements and mandates regular updates and inspections for aviation infrastructure and services. | It has specific references to minimizing noise pollution and impacts from aviation activities but does not refer to infrastructure-related environmental impacts. | The act provides for cooperative agreements with other states and international bodies. No other provisions for communication between operators and users are mentioned. | Roles and responsibilities are clearly defined, with an emphasis on collaboration between national and international aviation bodies. | It requires adaptation strategies through modernization plans and updates to aviation infrastructure. |
| **ICT** | | | | | | |
| BHUTAN TELECOMMUNICA-TIONS AND BROADBAND POLICY 2014 | There are no provisions for multi-hazard assessments or stress testing related to media infrastructure. | It does not explicitly mention safety requirements or backup systems for disruptions in media infrastructure. However, it mandates that telecom operators follow international standards and best practices for contingency planning and disaster management. | The policy encourages the use of energy-efficient technologies, clean energy, and effective e-waste management. | There are provisions for infrastructure-sharing and right-of-way approvals to promote efficient collaboration among operators (Clause 2.12). However, it does not specifically mention fostering engagement with users. | Roles and responsibilities of the media, government, and other actors are clearly defined. | There is no reference for requiring strategies to adapt to changing needs or future demands. |
| INFORMATION, COMMUNICATION AND MEDIA ACT 2018 | The act does not include multi-hazard assessments or stress testing requirements for ICT systems. | It sets the rules for the installation and maintenance of infrastructures in compliance with international norms and safety standards. It updates and the establishment of backup systems for emergency communication and the implementation of cybersecurity measures to protect ICT and media services from threats and attacks | The document does not explicitly encourage the use of environmental solutions to deliver infrastructure services in the sector | There is a focus on communication among operators and regulators, with a strong emphasis on coordination, transparency, and public engagement in service provision. It emphasizes mediation and other forms of alternative dispute resolution. It fosters communication among operators for disaster communications | Roles and responsibilities are clearly defined for different actors including policy makers, regulator, operators etc | The act mandates that the operators remain adaptable to emerging trends and ensure that services keep pace with technological advancements and the changing needs of the market (Section 2.14) |

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| **REVISED ICT ROADMAP 2015** | The roadmap does not include multi-hazard assessments or stress testing but includes a focus on ICT infrastructure security. | ICT security and resilience, with provisions for disaster management platforms and backup systems, are planned. | Environmental concerns are part of the broader goal of promoting sustainable ICT infrastructure, with initiatives like green data centres and energy-efficient ICT solutions. | Governance frameworks for the sector are included in the roadmap for better coordination and collaboration. | The roles and responsibilities for ICT governance, emphasizing inter-agency collaboration are clear in the roadmap. | The roadmap stresses the need for adapting ICT systems to changing needs and technological advancements through strategic implementation plans. |
| **WATER AND WASTEWATER** | | | | | | |
| **BHUTAN WATER POLICY 2007** | The policy emphasizes the need for flood control and management, including disaster management plans for Glacial Lake Outburst Floods (GLOF), but does not explicitly call for multi-hazard assessments or stress testing of water infrastructures for resilience. | There is a reference to flood control infrastructure and the importance of protecting water sources, but the policy does not include regular safety updates or backup systems. However, during shortages, a list of priority user groups is identified. | The policy is strong and clear on minimizing environmental impacts by promoting sustainable water resource management and protecting watersheds. | Communication and coordination are fostered among water resource managers and stakeholders, particularly at the river basin level. | Roles and responsibilities of various actors are clearly defined to ensure coordinated water management including water agencies, local governances, the private sector and communities. | The policy requires plans for sustainable water management, including the development of watershed protection measures and sustainable use of water resources. |
| **BHUTAN IWRM 2016** | GLOF and flood assessments are exclusively mentioned but it does not call for multi-hazard assessments or stress testing as part of water infrastructure development. | Structural safety measures are captured for flood mitigation only. Non-structural safety measures are designed through the water security index to monitor and assess water security, investments in water storage, irrigation systems, flood protection, and hydrological monitoring. | There is a strong emphasis on minimizing environmental impacts through sustainable water use, protecting water resources, and ensuring the environmental sustainability of water-related services. | There is no provision for coordination and communication platforms or channels. However, local communities and stakeholders are encouraged to participate in water management decisions, particularly through WUAs and basin-level planning. | The IWRM plan clearly defines roles and responsibilities of the various stakeholders in its implementation including government agencies, water users' associations, and basin-level committees. | In addressing water issues, the plan is precise on climate change, requiring adaptation in water management practices. Investments in water storage, irrigation systems, flood protection, and hydrological monitoring are required to adapt to climate change and improve water accessibility. |
| **WATER ACT OF BHUTAN 2011** | There is no provision for multi-hazard assessments or stress testing but it addresses the need for disaster preparedness and flood management. | Safety standards for water-related infrastructure, such as dams, reservoirs, and irrigation systems are addressed. It requires proper planning, design, construction, and maintenance of such infrastructure to ensure public safety and minimize the risk of accidents, such as floods or infrastructure failures. | There is a strong emphasis on minimizing environmental impacts through the prevention of water pollution and the sustainable use of water resources. | The Act calls for water-related institutions, including the establishment of River Basin Committees, but does not focus on user engagement for demand management. | There is a framework for implementing the Act through various government bodies and local authorities. Roles and responsibilities are clearly outlined for water authorities, River Basin Committees, and water users. | The Act mandates the preparation of the National Integrated Water Resources Management Plan (IWRM) for Bhutan. |

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| THE WASTE PREVENTION AND MANAGEMENT ACT 2009 | The act does not provide for multi-hazard assessments or stress testing of waste management systems. | Safety standards for managing hazardous waste are outlined, including packaging and health procedures, but there is no mention of regular safety updates or backup systems. | There is an emphasis on establishing mechanisms for the collection, segregation, and recycling of waste, encouraging sustainable waste management solutions. | Communication is fostered between implementing agencies and local authorities to coordinate waste management activities, but user engagement is not emphasized. | Roles and responsibilities are clearly defined for the various authorities and implementing agencies. | The regulation promotes the introduction of waste management systems that are adaptable to new needs, including the promotion of entrepreneurship in waste collection and recycling. |
| **EDUCATION AND HEALTH SECTOR** | | | | | | |
| NATIONAL EDUCATION POLICY | There is no provision for multi-hazard assessments, stress testing, or provisions to improve the education infrastructures based on such evaluations. | The policy outlines disaster management plans for schools and educational institutions, ensuring preparedness for emergencies | There is a reference to eco-friendly infrastructure with Bhutanese architectural designs in schools building practices. No other sustainable practices are provided for in the policy | There is an emphasis on framework for promoting effective collaboration between educational bodies, local governments, and schools | Roles and responsibilities are clarified through a governance framework | It does not provide for plans and strategies for adapting to changing needs in the context of infrastructure resilience building |
| NATIONAL HEALTH POLICY | The health policy addresses multi-hazard preparedness through the national emergency preparedness plan. However, structural resilience is not provided for in the policy. | The policy emphasizes safety requirements and includes the provision for regular monitoring and quality improvement of health services. | It promotes safe and appropriate waste disposal methods to reduce potential health risks (Clause 11.2.h) and through multi-sectoral collaboration on environmental issues. | It fosters communication among health sector operators and emphasizes the importance of multi-sectoral collaboration including partnerships with the private sector, community participation, international partnerships etc. | The roles and responsibilities of health sector actors are clearly defined. | The policy requires health operators to adapt to changing needs, with strategies in place for evolving healthcare demands, such as addressing changing disease patterns and health technology needs. |

## ANNEX III: PRINCIPLES OF RESILIENT INFRASTRUCTURE

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| **PRINCIPLE 1 (CONTINUOUSLY LEARNING) AIMS TO DEVELOP AND UPDATE UNDERSTANDING AND INSIGHT INTO INFRASTRUCTURE RESILIENCE** | |
| **PLANNING** | Set-up a system to ensure the dissemination of lessons learnt from past disasters to inform future planning (P1.3) |
| **DELIVERY / CONSTRUCTION** | Review and validate the climate and disaster scenarios used for infrastructure project preparation and design (P1.1) |
| **OPERATION AND MAINTENANCE** | Enhance monitoring, sensing and early-warning systems to minimize outages of critical services (P1.2.)<br>Require operators to carry out regular stress tests to identify vulnerabilities and options for improvement (P1.4) |
| **PRINCIPLE 2 (PROACTIVELY PROTECTED) AIMS TO DETERMINE AND INCREASE THE LEVEL OF HAZARD/THREAT PREPAREDNESS AND RESPONSE** | |
| **PLANNING** | Develop a pipeline of safety-improvement interventions (P2.1)<br>Identify critical components of national infrastructure systems and prioritize them for necessary upgrades (P2.2.)<br>Establish cross-sectoral planning committees to ensure all infrastructure sectors coordinate efforts and share data about cascading risks (P2.3) |
| **DELIVERY / CONSTRUCTION** | Require infrastructure design to include safe-to-fail solutions (e.g., plan for backup energy-supply solutions and design for hazardous substance controls) (P2.5)<br>Require resilience assessments and interdependency analysis in infrastructure projects (P2.3)<br>Require the development of long-term maintenance plans as part of the initial approval process for infrastructure projects (P2.7)<br>Ensure that project appraisal takes a long-term approach and considers lifecycle costs, including those related to potential disasters (P2.8) |
| **OPERATION AND MAINTENANCE** | Build the capacity of local infrastructure operators to deal with disruptions (e.g., drills) (P2.4).<br>Ensure that critical services can be delivered through a diversity of scales: national, regional and local and operationalize redundancy for smaller-scale solutions (P2.6)<br>Establish dedicated funds specifically for ensuring proper maintenance (P2.7) |
| **PRINCIPLE 3 (ENVIRONMENTALLY INTEGRATED) AIMS TO WORK IN A POSITIVELY INTEGRATED WAY WITH THE NATURAL ENVIRONMENT.** | |
| **PLANNING** | Promote the use of environmental information in infrastructure planning (P3.3) |
| **DELIVERY / CONSTRUCTION** | Conduct audits to control the environmental impacts of infrastructure systems (P3.1)<br>Include in project preparation documents an evaluation of the cost benefits of environmental solutions in comparison to other conventional or grey alternatives (P3.2)<br>Identify local resources and encourage their use for infrastructure projects through selection criteria in procurement (P3.5) |
| **OPERATION AND MAINTENANCE** | Lay down policies and regulations so that contractors and operators maintain the surrounding natural environment to reduce the threat of disruptions to critical services (P3.4) |

| LIFECYCLE STAGE | EXAMPLES OF INTERVENTIONS (NUMBER IN PARENTHESIS PROVIDES THE REFERENCE TO THE RELATED ACTION INCLUDED IN THE PRINCIPLES FOR RESILIENT INFRASTRUCTURE PUBLICATION) |
|---|---|
| **PRINCIPLE 4 (SOCIALLY ENGAGED) AIMS TO DEVELOP ACTIVE ENGAGEMENT, INVOLVEMENT AND PARTICIPATION ACROSS ALL LEVELS OF SOCIETY** | |
| **PLANNING** | Define guidelines for providing clear emergency messages (e.g., select the lowest literacy level for emergency messages that are compatible with the literacy level of the population) (P4.1) |
| **DELIVERY / CONSTRUCTION** | Ensure contractors and operators incorporate appropriate channels for emergency communications in the project design (P4.1) |
| **OPERATION AND MAINTENANCE** | Define obligations for infrastructure sectors to adopt incentive policies or strategies for demand reduction, demand shifting, or demand avoidance (P4.3)<br>Promote education about resiliency, taking advantage of formal education programmes and local media, depending on the target audience (P4.2)<br>Encourage operators to develop community participation programmes (P4.4) |
| **PRINCIPLE 5 (SHARED RESPONSIBILITY) AIMS TO SHARE INFORMATION AND EXPERTISE FOR COORDINATED BENEFITS** | |
| **PLANNING** | Engage with stakeholders and experts to select or devise information-sharing standards and incorporate them into regulation and law (P5.1)<br>Work with stakeholders and experts to encourage multi- and trans-sectoral collaboration for better infrastructure resilience (P5.2)<br>Develop and formalize data-security regulations for infrastructure resilience (P5.5) |
| **DELIVERY / CONSTRUCTION** | Collect construction and operational data formatted in compliance with relevant standards (P5.1) |
| **OPERATION AND MAINTENANCE** | Creates and utilizes data-sharing platforms with sufficiently robust communication channels to disseminate information to relevant stakeholders effectively (P5.4)<br>Collate and share data rapidly during disruptions to enable a coordinated response (P5.4) |
| **PRINCIPLE 6 (ADAPTIVELY TRANSFORMING) AIMS TO ADAPT AND TRANSFORM TO CHANGING NEEDS.** | |
| **PLANNING** | Monitor demand and ensure that capacity can meet expected future demand either through demand reduction or increasing capacity (P6.4) |
| **DELIVERY / CONSTRUCTION** | Design systems according to local resources and capacity (P6.1)<br>Provide designs that allow usage to be measured and enable future changes to capacity (P6.2) |
| **OPERATION AND MAINTENANCE** | Monitor compliance with override capacity requirements allowing for human discretion, and report on non-compliance (P6.5) |

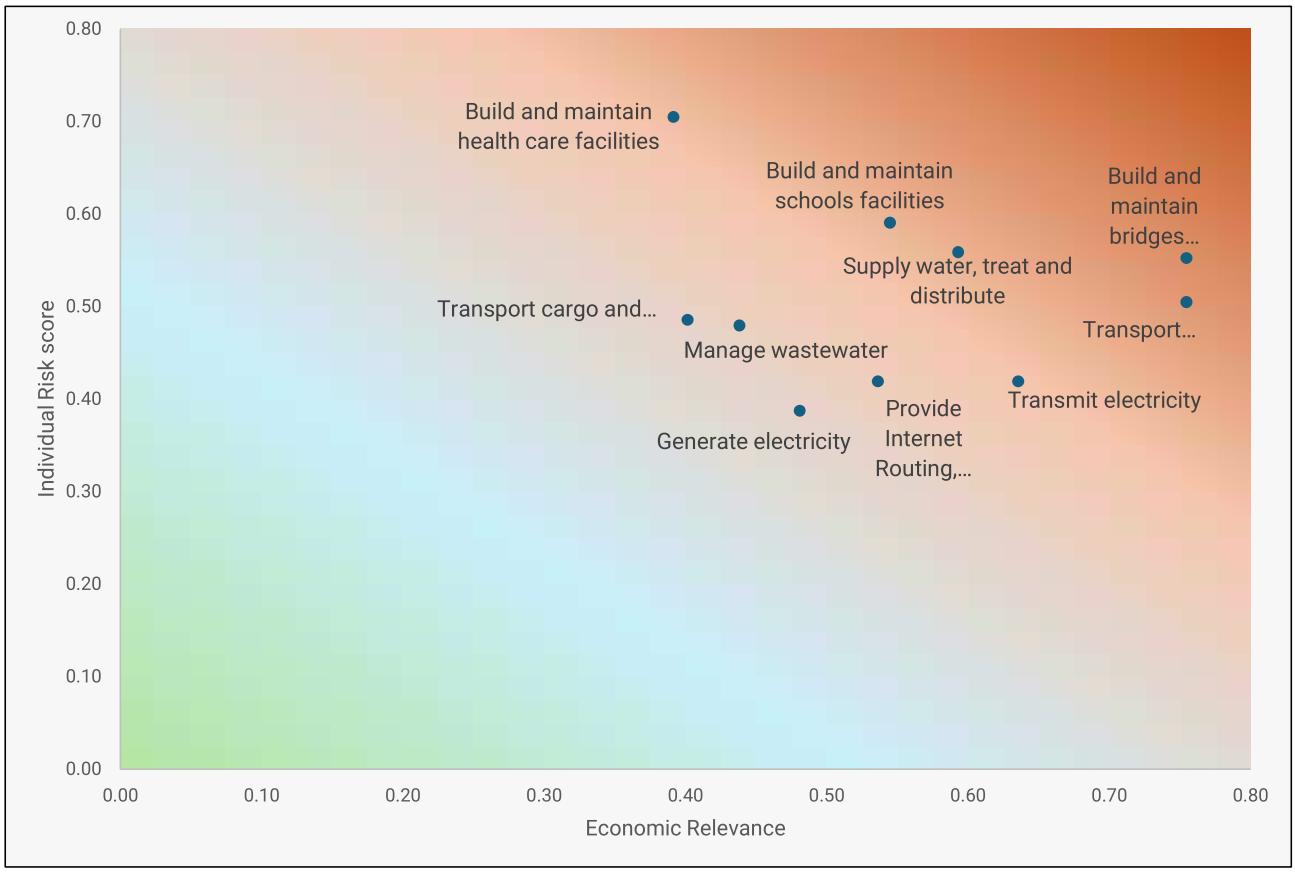
# ANNEX IV: STRESS TEST RESULTS

## INFRASTRUCTURE CRITICAL FUNCTIONS

The table below assists in prioritizing infrastructure critical functions based on their importance for maintaining the economy in the country and the risk they are exposed to. The Cascading Risk column provides additional information about the risk that an infrastructure function is facing. High cascading risk means that the critical function is vulnerable to disruptions from other functions (as it depends on them).

| | *Importance of the Infrastructure Critical Functions based on their support to the Economic Sectors* | | *Level of risk of the Infrastructure Critical Functions posed by the selected hazards* | *Cascading risk from dependence between critical functions in disaster scenarios* |
|---|---|---|---|---|
| INFRASTRUCTURE CRITICAL FUNCTIONS | IMPACT ON THE ECONOMY | CASCADING IMPACT ON THE ECONOMY | INDIVIDUAL RISK | CASCADING RISK |
| Supply water, treat and distribute | 0.59 | 0.39 | 0.56 | 0.27 |
| Manage wastewater | 0.44 | 0.25 | 0.48 | 0.30 |
| Transport cargo and passengers by air | 0.40 | 0.25 | 0.49 | 0.36 |
| Transport cargo and passengers by road | 0.75 | 0.50 | 0.50 | 0.12 |
| Build and maintain bridges and tunnels | 0.75 | 0.58 | 0.55 | 0.22 |
| Generate electricity | 0.48 | 0.43 | 0.39 | 0.39 |
| Transmit electricity | 0.64 | 0.46 | 0.42 | 0.41 |
| Provide Internet Routing, Access, and Connection | 0.54 | 0.35 | 0.42 | 0.46 |
| Build and maintain schools facilities | 0.54 | 0.16 | 0.59 | 0.57 |
| Build and maintain health care facilities | 0.39 | 0.26 | 0.70 | 0.67 |

## INFRASTRUCTURE CRITICAL FUNCTIONS: RISK AND ECONOMIC RELEVANCE

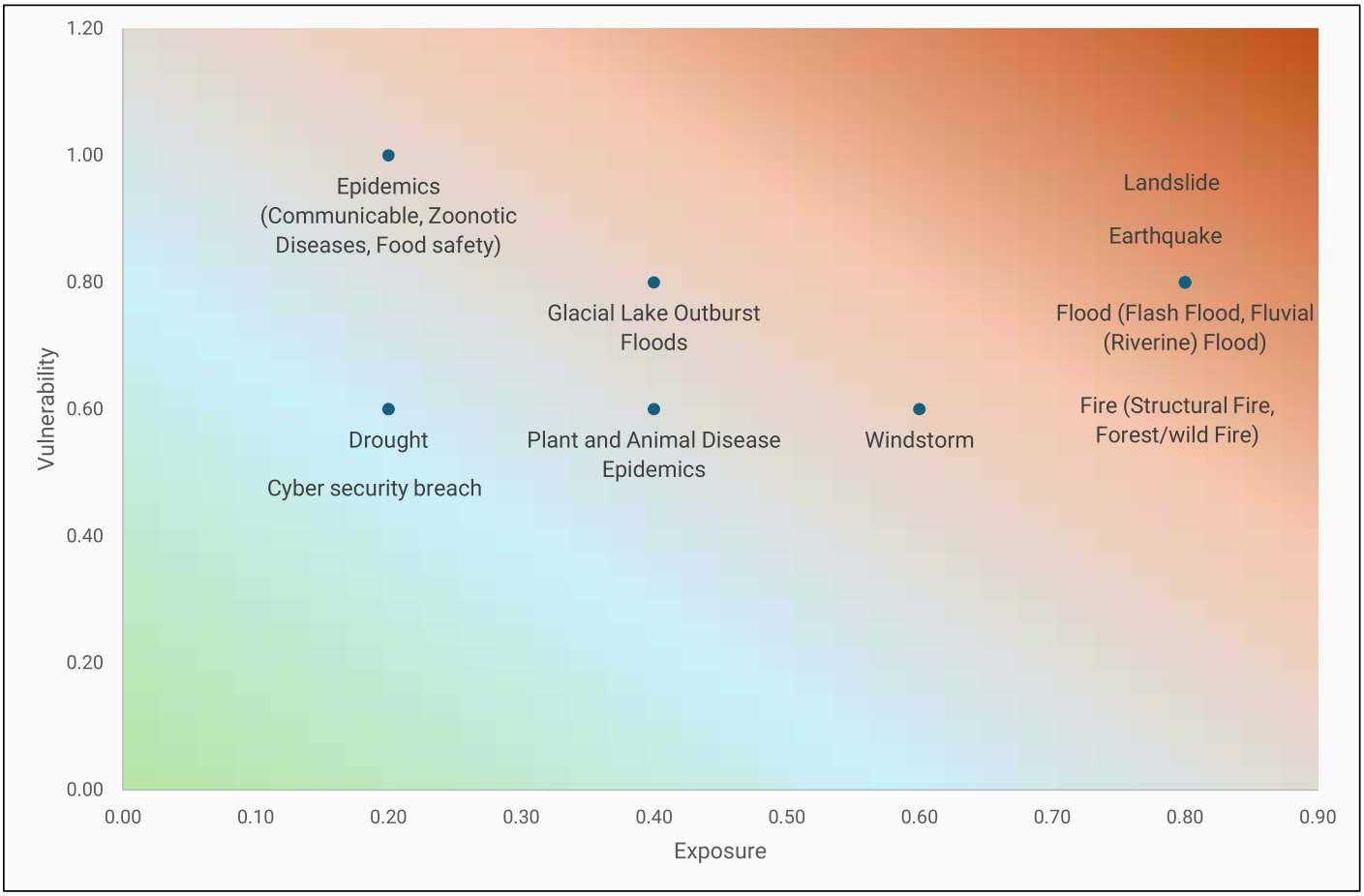


## HAZARDS

The table below assists in prioritizing hazards based on their impacts on critical functions and the economy. The Exposure and Vulnerability columns provide information on the likelihood and potential impacts of each hazard on the overall infrastructure systems, as well as a Risk score (weighted average of the exposure and vulnerability scores.

| | *Relevance of Hazards based on their impact to critical functions and their relevance to the Economic Sectors* | EXPOSURE AND VULNERABILITY OF INFRASTRUCTURE SYSTEMS TO SELECTED HAZARDS | | |
|---|---|---|---|---|
| HAZARDS | IMPACT TO THE ECONOMY | EXPOSURE | VULNERABILITY | RISK SCORE WEIGHTED AVERAGE |
| Glacial Lake Outburst Floods | 0.49 | 0.40 | 0.80 | 0.60 |
| Flood (Flash Flood, Fluvial (Riverine) Flood) | 0.64 | 0.80 | 0.80 | 0.80 |
| Drought | 0.45 | 0.20 | 0.60 | 0.40 |
| Windstorm | 0.46 | 0.60 | 0.60 | 0.60 |
| Landslide | 0.65 | 0.80 | 0.80 | 0.80 |
| Earthquake | 0.77 | 0.80 | 0.80 | 0.80 |
| Fire (Structural Fire, Forest/wild Fire) | 0.48 | 0.80 | 0.80 | 0.80 |
| Plant and Animal Disease Epidemics | 0.24 | 0.40 | 0.60 | 0.50 |
| Epidemics (Communicable, Zoonotic Diseases, Food safety) | 0.26 | 0.20 | 1.00 | 0.60 |
| Cyber security breach | 0.34 | 0.20 | 0.60 | 0.40 |

## EXPOSURE AND VULNERABILITY OF INFRASTRUCTURE SYSTEMS TO HAZARDS



## ECONOMIC SECTORS

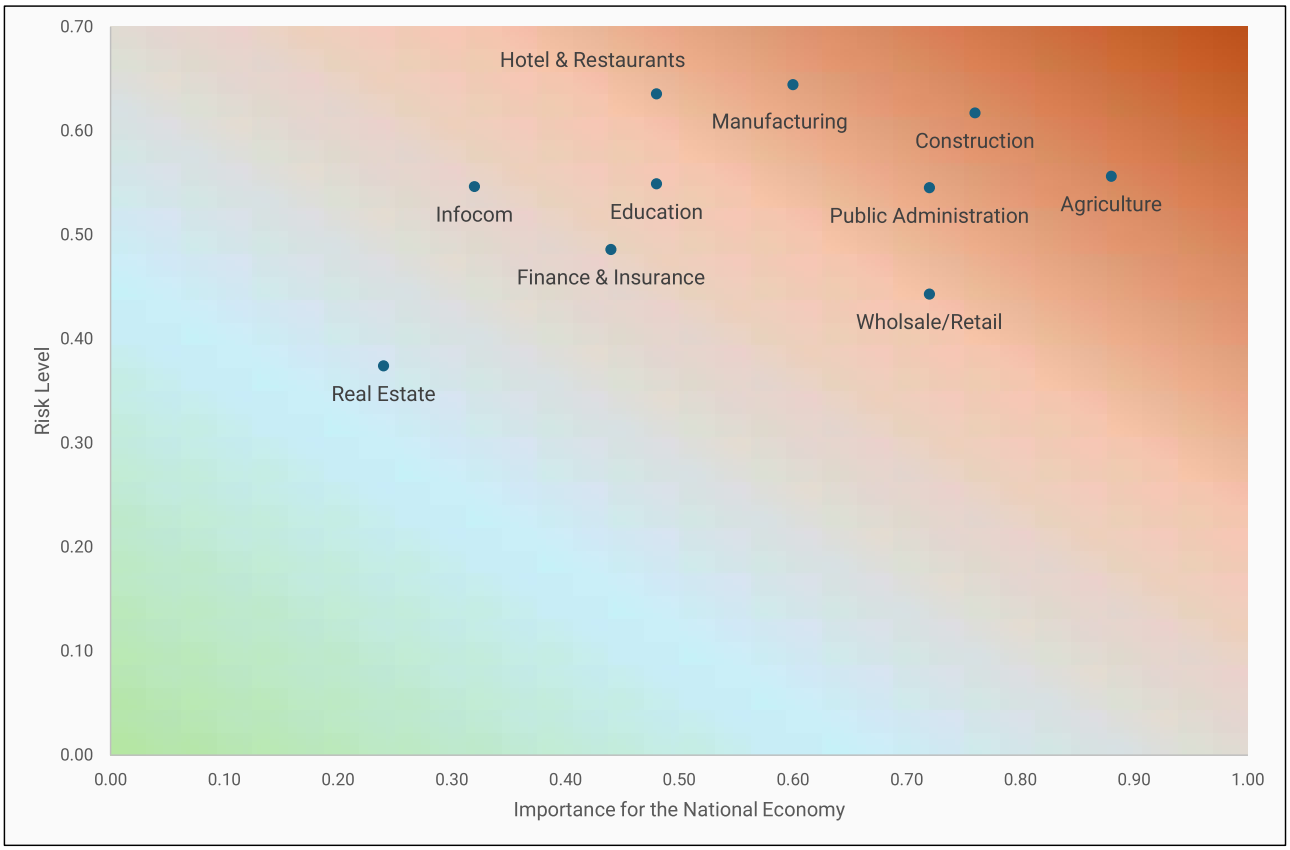
The table below assists in prioritizing economic sectors based on a) their contribution to the GDP and to the creation of jobs (average between the two); b) the level of risk posed to the economic sectors due to possible failures of the critical functions on which they depend.

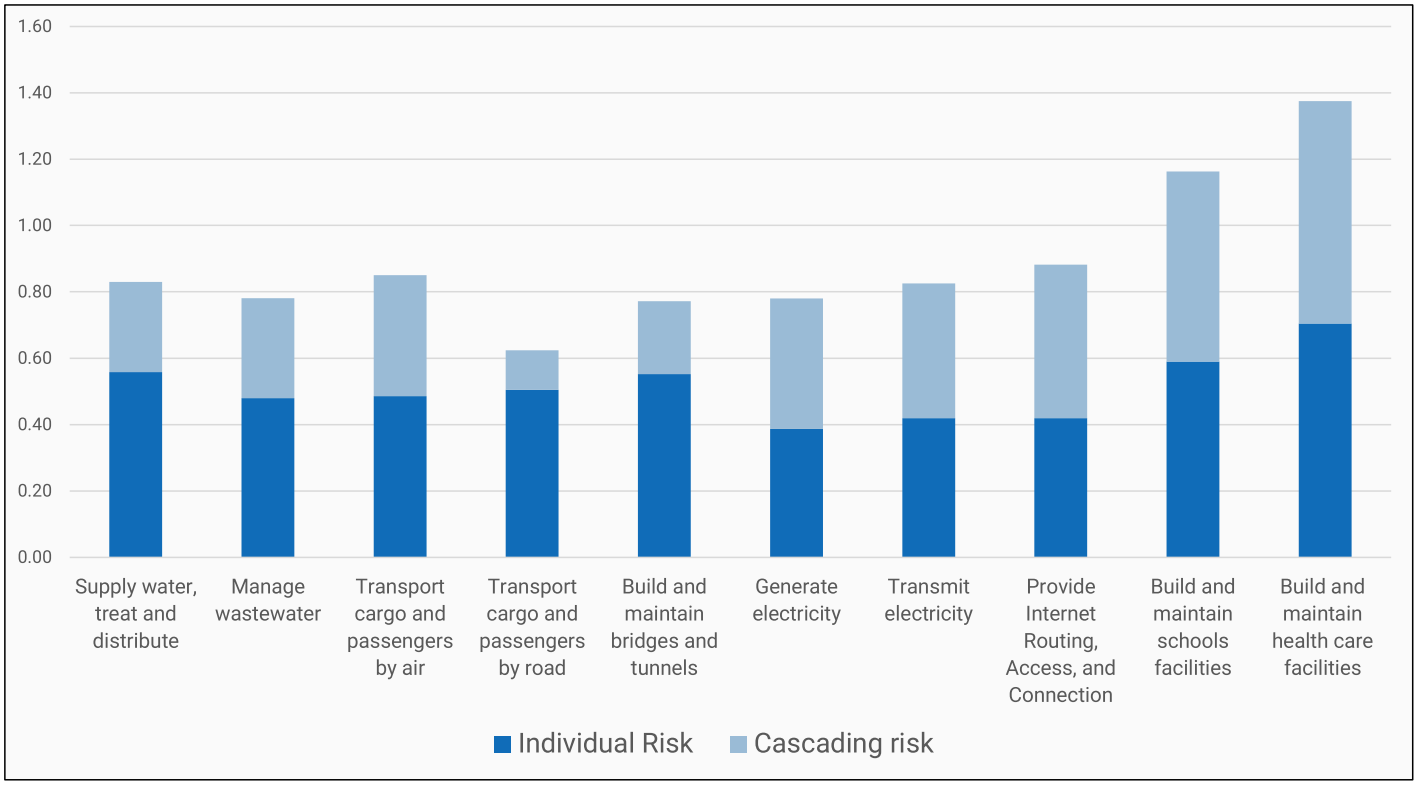
*Importance of Economic Sector based on its contribution to jobs and GDP*

*Level of risk of the Economic Sectors based on the risk of the Critical Functions on which they depend*

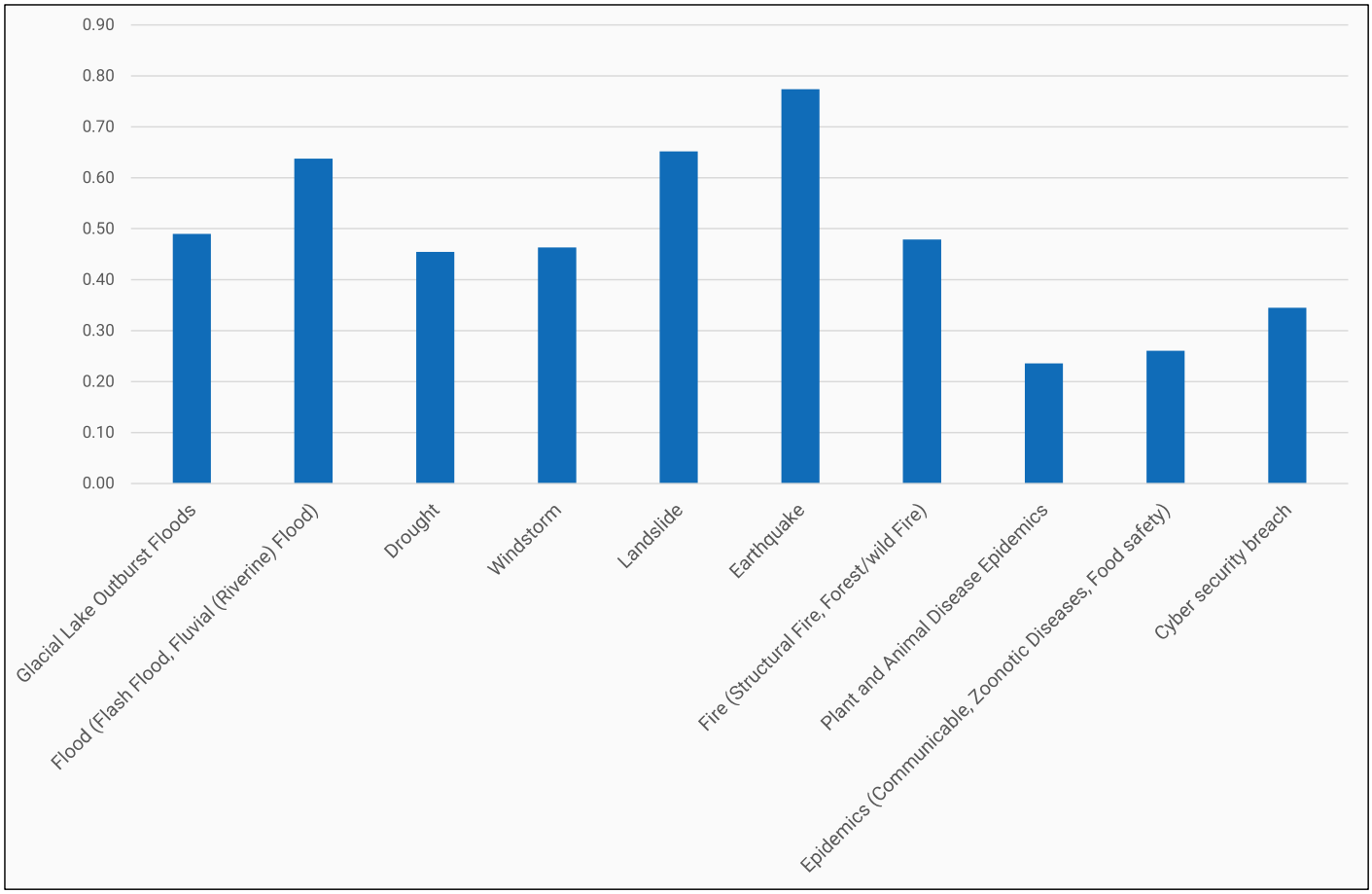
| | | EXPOSURE AND VULNERABILITY OF INFRASTRUCTURE SYSTEMS TO SELECTED HAZARDS | | |
|---|---|---|---|---|
| HAZARDS | IMPACT TO THE ECONOMY | EXPOSURE | VULNERABILITY | RISK SCORE WEIGHTED AVERAGE |
| Glacial Lake Outburst Floods | 0.49 | 0.40 | 0.80 | 0.60 |
| Flood (Flash Flood, Fluvial (Riverine) Flood) | 0.64 | 0.80 | 0.80 | 0.80 |
| Drought | 0.45 | 0.20 | 0.60 | 0.40 |
| Windstorm | 0.46 | 0.60 | 0.60 | 0.60 |
| Landslide | 0.65 | 0.80 | 0.80 | 0.80 |
| Earthquake | 0.77 | 0.80 | 0.80 | 0.80 |
| Fire (Structural Fire, Forest/wild Fire) | 0.48 | 0.80 | 0.80 | 0.80 |
| Plant and Animal Disease Epidemics | 0.24 | 0.40 | 0.60 | 0.50 |
| Epidemics (Communicable, Zoonotic Diseases, Food safety) | 0.26 | 0.20 | 1.00 | 0.60 |
| Cyber security breach | 0.34 | 0.20 | 0.60 | 0.40 |

## ECONOMIC SECTORS IMPORTANCE AND LEVEL OF RISK TO INFRA FAILURES



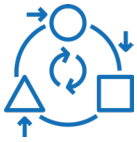



## IMPACT TO THE ECONOMY THROUGH THE DISRUPTION OF CRITICAL INFRASTRUCTURE FUNCTIONS



## ANNEX V: WATER SECTOR RESILIENCE ANALYSIS

| PRINCIPLE FOR RESILIENT INFRASTRUCTURE | FINDINGS FOR BHUTAN WATER SECTOR – KEY RESILIENCE GAPS | RECOMMENDATIONS |
|---|---|---|
| **CONTINUOUSLY LEARNING**  | Some parts of the water sector in Bhutan are well advanced with effective monitoring in place, however, gaps were identified in the understanding of water resources and quality.<br><br>Local government doesn't have guidelines for potable water, so different types of water (irrigation water, potable water, etc.) are managed without clear guidelines.<br><br>Climate and disaster resilient infrastructure – gap<br>Adoption of technology to improve water quality | Improve monitoring and control systems for water systems, including SCADA systems and collection of real time water quality information.<br><br>Establish guidelines for local government water management and support their implementation |
| **PROACTIVELY PROTECTED**  | Water sector infrastructure in Bhutan has been exposed to a range of hazards that have resulted in disruptions to services.<br><br>Issues with pipelines (leaks, non-revenue water, damage in disaster events) was identified as a major issue reducing resilience of the water sector, with insufficient maintenance and asset management programs.<br><br>Lack of adequate treatment of drinking water was identified as an issue in regional areas. | Development of improved mechanisms for funding and planning pipe networks<br><br>Establish a national research program for water treatment and management, drawing on emerging needs of organisations and disseminate and implement findings<br><br>Develop contingency plans for each critical water function |
| **ENVIRONMENTALLY INTEGRATED**  | Water sources are not well protected from land based activities and subsequent pollution, nor is the sustainable yield of water sources well understood.<br>Some source protection activities are underway, but improved monitoring on their effectiveness to protect water resources appears to be a gap. | Development of national water resource inventory |
| **SOCIALLY ENGAGED**  | The water sector involves all a range of stakeholders – from government, utilities, NGOs, and communities, with different stakeholders playing a role in the management and delivery of water functions to community members.<br><br>However, gaps exist in terms of effective communication of water related messaging to community members at the right time to ensure their safe and reliable access to water.<br><br>Water sector stakeholders identified a lack of suitably qualified experts in the sector (including local government). | Support water sector organisations to build capacity of staff and community members involved in water management through increased training and education<br><br>Improve regulation and enforcement of existing policy relating to source protection, water and wastewater regulations |

| | | |
|---|---|---|
| **SHARED RESPONSIBILITY**  | Understanding responsibilities across organisations appears to be patchy (for example sediment dams require coordination between Dept. of Geology and Mines and the Ministry of Infrastructure and Transport, leaving a governance gap). Engagement with local stakeholders related to water management is lacking. Coordination works better in Thimphu because all the government agencies are located here, but it is not the same in other provinces.<br><br>Stakeholders identified a need to improve coordination and collaboration between water sector organisations.<br><br>Bhutan shares international boundaries with China and India. Bhutan has cooperative relationships with India.<br><br>In depth mechanisms to collaborate with other critical infrastructure is limited | Establish formal mechanisms for clarification of responsibilities, collaboration and information sharing across the water sector<br><br>Develop a GIS based nationwide inventory on water infrastructure, providing a common and easy access to the inventory for stakeholders |
| **ADAPTIVELY TRANSFORMING**  | Challenges with planning and maintenance of water / wastewater / flood protection assets was identified, with a lack of standardised guidance a gap.<br><br>Access to development and climate funds and development of financial capacity to meet O&M requirements | Improve and standardise decision-making for water infrastructure / flood mitigation projects by establishing clear guidelines for risk assessment, climate change adaptation and cost benefit analysis |

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