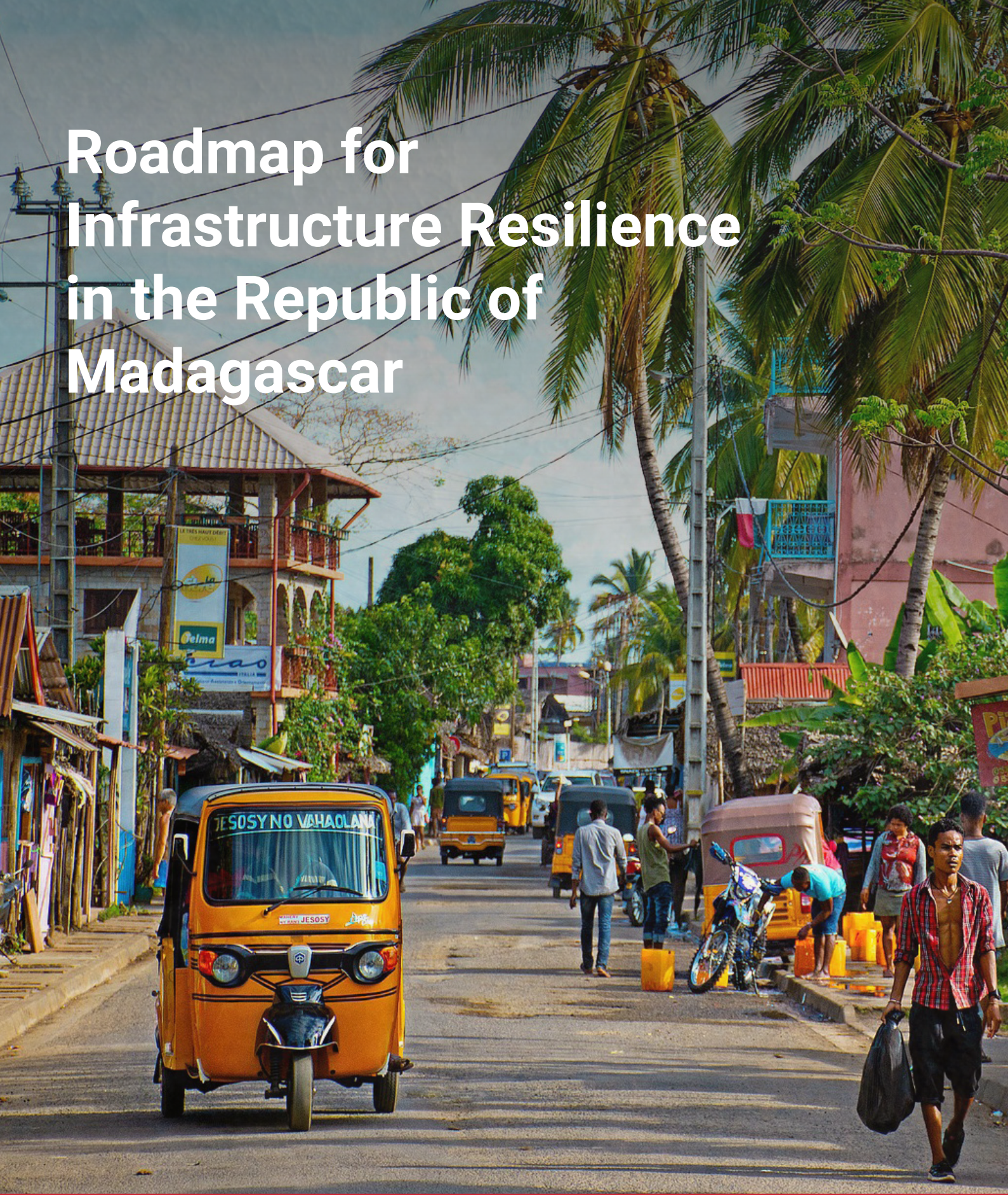
Roadmap for Infrastructure Resilience in the Republic of Madagascar



Government of Madagascar

REPOBLIKAN'I MADAGASIKARA
Fitiavana - Tanindrazana - Fandrosoana

In collaboration with:

UNDRR
UN Office for Disaster Risk Reduction

CDRI
Coalition for Disaster Resilient Infrastructure

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LIST OF ABBREVIATIONS

ADEMA	Aéroports de Madagascar (Airports of Madagascar)
ADER	Agence de Développement de l'Electrification Rurale Rural Electrification Development Agency
AFD	Agence Française de Développement (French Cooperation Agency)
AFDB	African Development Bank
ANDEA	Autorité Nationale De l'Eau et l'Assainissement (National Water and Sanitation Authority)
APIPA	Autorité pour la Protection contre les Inondations de la Plaine d'Antananarivo (Antananarivo's Flood Protection Authority)
APMF	Agence Portuaire Maritime et Fluviale (Maritime and River Port Authority)
ARM	Agence routière de Mada¬gas¬car (Madagascar Road Authority)
ARTEC	Autorité de Régulation des Technologies de Communication (Communication Technologies Regulatory Authority)
BNGRC	Bureau National de la Gestion des Risques et des Catastrophes (National Office for Risk and Disaster Management)
CCGRC	Comité Communal de GRC au niveau des communes (DRM Committee at commune level)
CDGRC	Comité de District de GRC au niveau des districts (DRM Committee at district level)
CDRI	Coalition for Disaster Resilient Infrastructure
CERC	Contingent Emergency Response Component
CERVO	Centre d'Études, de Réflexion, de Veille et d'Orientation (Center for studies, reflection, monitoring, and orientation)
CLGRC	Comité Local de GRC au niveau des fokontany (DRM committee at local/fokontany level)
CMA CGM	Compagnie Maritime d'Affrètement – Compagnie Générale Maritime (Maritime Chartering Company – General Maritime Company)
CPGU	Cellule de Prévention et d'Appui à la Gestion des Urgences (Emergency Prevention and Management Support Unit)
CRGRC	Comité Régional de GRC au niveau des régions (DRM Committee at Regional level)
CRIC	Comité de Réflexion des Intervenants aux Catastrophes (Disaster Response Advisory Committee)
CSR	Corporate Social Responsibility
DGM	Direction Générale de la Météo (General Directorate for Meteorology)
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EWS	Early Warning System
FID	Fonds d'Intervention de Développement (Development Intervention Fund)
FNE	FNE: Fonds National d'Electrification (National Electrification Fund)
FNED	Fonds National d'Energie Durable (National Sustainable Energy Fund)
FNRE	Fonds National sur les Ressources en Eau (National Water Resources Fund)
FRM	Fonds Routiers Madagascar (Madagascar road fund)
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GPM	Global Precipitation Measurement Mission
ICT	Information and Communication Technologies
IEM	Initiative Emergence Madagascar (Madagascar Emergence Initiative)
IMERG	Integrated Multi-satellitE Retrievals
IMO	International Maritime Organization
INSTAT	Institut National de la Statistique (National Institute of Statistics)
ITU	International Telecommunication Union
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
LCPDP	Least Cost Power Development Plan
Ligne FCE	Fianarantsoa—Côte Est railroad
Ligne TCE	Tananarive—Côte Est railroad
MADARAIL	Madagascar Railways
JIRAMA	Jiro sy Rano Malagasy
MDAT	Ministère de la Décentralisation et de l'Aménagement du Territoire (Ministry of Decentralization and Land Use Planning)
MEAH	Ministère de l'Eau, de l'Assainissement et de l'Hygiène (Ministry of Water, Sanitation and Hygiene)
	Mise En Compatibilité des Investissements avec l'Environnement (Compatibility of Investments

MECIE	with the Environment)
MEDD	Ministère de l'Environnement et du Développement Durable (Ministry of Environment and Sustainable Development)
MEF	Ministère de l'Economie et des Finances (Ministry of Economy and Finance)
MEH	Ministère de l'Energie et des Hydrocarbures (Ministry of Energy and Hydrocarbons)
MICTSL	Madagascar International Container Terminal Services Limited
MMT	Ministère des Transports et de la Météorologie (Ministry of Transport and Meteorology)
MNDPT	Ministère du Développement Numérique, de la Transformation Digitale, des Postes et des Télécommunications (Ministry of Digital Development, Digital Transformation, Post and Telecommunications)
MTP	Ministère des Travaux Publiques (Ministry of Public Works)
NAP	National Adaptation Plan
NGO	Non-Gouvernmental Organization
NIRIPG	Norme Nationale pour les Infrastructures Routières Résistantes aux Inondations et aux Phénomènes Géologiques (National Standards applicable to Road Infrastructure resistant to Floods and Geological Phenomena
NPE	Nouvelle Politique Energétique (New Energy Policy)
ONE	Office Nationale de l'Environnement (National Environment Office)
ORE	Office de Régulation de l'Electricité (Office for Electricity Regulation)
PAGOSE	Projet d'Amélioration de la Gouvernance et des Opérations dans le Secteur de l'Electricité (Project for the Improvement of Governance and Operations in the Electricity Sector)
PARSE	Programme d'Appui à la Réforme du Secteur de l'Énergie (Energy Sector Reform Support Programme)
PCG	Ports à Concession Globale (Ports with Global Concession)
PGA	Ports à Gestion Autonome (Autonomous Ports)
PIN	Ports d'Intérêt National (Ports of National Interest)
PIR	Ports d'Intérêt Régional (Ports of Regional Interest)
PNE	Plan National d'Electrification (National Electrification Plan)
PNEAH	Projet de Politique Nationale de l'Eau et de l'Assainissement Hydrique (National Water and Water Sanitation Policy)
PNRRC	Plateforme Nationale de la Réduction des Risques de Catastrophes (National Platform for Disaster Risk Reduction)
PNTM	Projet de Politique Nationale de Transport Maritime (Draft national maritime Transport Policy)
PRIRITEM	Projet d'Interconnexion et de Renforcement des Réseaux de Transport d'Energie Electrique à Madagascar (Power Transmission Network Reinforcement and Interconnection Project in Madagascar)
PSE	Programme Sectoriel Éducation (Education Sector Program)
PSHP	Plateforme Humanitaire du Secteur Privé (Private Sector Humanitarian Platform)
PSNA	Politique et Stratégie Nationale pour l'Assainissement (National Sanitation Policy and Strategy)
RN	Routes Nationales (National Roads)
RNP	Routes Nationales Primaires (Primary National Roads)
RSSP	Projet de durabilité du secteur routier (Road sector sustainability project)
SESA	Strategic Environmental and Social Assessment
SMMC	Société de Manutention des Marchandises Conventionnelles (Conventional Cargo Handling Company)
SNE	Stratégie Nationale de l'Electrification (National Electrification Strategy)
SPAT	Société de Port à gestion Autonome de Toamasina
SPI	Standard Precipitation Index
SWIO	Southwest Indian Ocean
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNICEF	United Nations Children's Fund
UNITAR	United Nations Institute for Training and Research
UNOPS	United Nations Office for Project Services
UNOSAT	United Nations Satellite Centre
USAID	United States Agency for International Development
WHO	World Health Organization
WWF	World Wildlife Fund

FOREWORD

Improving infrastructure resilience is a priority objective for the Government of Madagascar as the country faces considerable annual economic losses due to climate change-related and other disasters.

Infrastructure is critical for driving economic growth and enhancing the living standards of the population through facilitating the transport of goods, providing irrigation for agriculture, expanding electrification and access to clean energy, and ensuring access to clean drinking water, among others.

In this context, the Roadmap for Infrastructure Resilience in Madagascar is a strategic document for the country's development. It outlines a comprehensive action plan aimed at minimizing disaster risks in the country.

I therefore urge all stakeholders to expedite the implementation of this Roadmap and encourage development partners to lend their full support.

This Roadmap has been developed in a collaborative effort between the United Nations Office for Disaster Risk Reduction (UNDRR), the Coalition for Disaster Resilient Infrastructure (CDRI) and the Emergency Prevention and Management Support Unit (Cellule de Prévention et d'appui à la Gestion des Urgences, CPGU) of Madagascar.

It builds upon the foundational work initiated by the CPGU, focusing on the implementation of construction standards designed to enhance the resilience of infrastructure against cyclones, floods, and other hazards.

The Roadmap is the culmination of extensive collaboration among sectors involved in critical infrastructure in Madagascar, including the Ministries of Public Works, Transport and Meteorology, Land Use Planning, Water, Sanitation and Hygiene, Energy, Digital Development, Post and Telecommunications, and Education, as well as road and maritime regulatory authorities and key stakeholders dedicated to disaster risk management and reduction.

The broad participation of various institutions highlights the importance and interest in enhancing infrastructure resilience against disasters, including the impacts of climate in Madagascar. Ultimately, this focus on resilience indicates a major strategic, social, and economic challenge for the country, positioning infrastructure resilience as a vital lever for sustainable development.

Mrs. RABEVOHITRA Bako Nirina
Acting Executive Secretary of the CPGU/Prime Minister

EXECUTIVE SUMMARY

The collaboration between institutions in Madagascar, the United Nations Office for Disaster Risk Reduction (UNDRR), and the Coalition for Disaster Resilient Infrastructure (CDRI), with support from the United Nations Satellite Centre (UNOSAT) has led to the identification of nearly fifty key measures to enhance infrastructure resilience in Madagascar.

These measures collectively serve as a Roadmap for the country in a crucial area of sustainable development, addressing the significant infrastructure damage estimated at nearly $100 million annually, and which has far-reaching social, environmental, and economic repercussions. The impact of Cyclone Gamane, which struck northern Madagascar in March 2024, illustrates this challenge. It affected approximately 89,000 people, damaged 18,787 homes, and severely impacted road infrastructure, with reconstruction costs projected at $76 million.

This Roadmap provides a detailed presentation of recommended measures, categorizing them into cross-cutting recommendations applicable to all sectors and sector-specific recommendations tailored to the unique needs of transport, energy, water, telecommunications, and education.

The measures were identified through a comprehensive process that incorporates:

(i) a systematic examination of the country's existing institutional and regulatory framework for infrastructure,
(ii) an in-depth analysis of sector-specific disaster risks using geolocated data, and
(iii) an evaluation of current domestic practices against international standards for infrastructure resilience.

The recommended measures concentrate on the following five focus areas:

DATA, MONITORING AND EVALUATIONS

The critical role of effective data management in developing and maintaining hazard-resistant infrastructure, thereby fostering a proactive risk management strategy was emphasized by stakeholders. To overcome existing limitations, the Government plans to enhance geolocated data capabilities by equipping ministries with appropriate tools and assigning focal points in each ministry. A digital database is to be established for mapping infrastructure vulnerabilities, leveraging data gathered from this Roadmap while integrating digitized construction standards. BNGRC's center for studies, reflection, monitoring, and orientation (Centre d'études, de réflexion, de veille et d'orientation, CERVO) will facilitate this effort as it has the responsibility of setting up an interactive database to centralize territorial risk analyses. It also ensures the collection, processing, and analysis of information, facilitating the ability to guide and anticipate responses while ensuring effective data management.

Additionally, the Roadmap recommends implementing regular stress tests and developing a data-sharing charter to foster collaboration among institutions, while also requesting information from private operators about service interruptions and risk management strategies.

CAPACITY BUILDING

The Roadmap outlines a strategy for training staff from relevant sectors in infrastructure warning and monitoring systems through monthly meetings and workshops aimed at ensuring service continuity during disasters. It also highlights the importance of establishing specific programs to educate decision-makers on nature-based solutions (NbS) and innovative environmental assessment techniques. Furthermore, awareness-raising campaigns will be deployed to promote and familiarize stakeholders with the newly developed standards.

INFRASTRUCTURE PROJECTS (STRUCTURAL MEASURES)

The Roadmap highlights the dual focus on improving governance and investing in physical assets. It advocates public-private partnerships (PPPs) to build resilient infrastructure by establishing a clear legal and regulatory framework that enhances transparency and financial incentives. It promotes community-based participatory strategies for road maintenance and encourages investment in the circular economy to mitigate flooding risks from waste-clogged drainage systems. Additionally, the Roadmap supports the strengthening of water network connections in high-lying areas to lessen reliance on tanker supplies. The Roadmap also recommends adopting a standardized, legislated assessment process for infrastructure projects that incorporates risks and climate change considerations, utilizing tools like cost-benefit analysis. Finally, it emphasizes the need to reactivate road funds and secure consistent funding for road maintenance.

GOVERNANCE AND COORDINATION

The Roadmap outlines several key governance recommendations, including the appointment of a focal point to oversee the implementation of actions for effective monitoring. It encourages improved coordination among ministries through quarterly technical meetings and the use of existing land use planning tools and other relevant sectoral documents. This collaborative strategy aims to improve the planning and execution of infrastructure projects, fostering their resilience. The Roadmap underscores the importance of bolstering the independence and sovereignty of regulatory authorities within the transport sector to ensure transparency throughout construction operations, from procurement to inspections of completed works, particularly concerning adherence to construction standards.

POLICIES, STANDARDS AND REGULATIONS

This Roadmap identifies several areas for enhancing the framework of policies, standards, and regulations related to infrastructure planning, construction, and maintenance. It provides recommendations to update infrastructure standards to incorporate resilience concepts and developing new standards for underrepresented sectors such as telecommunications, energy, and rail transport. Furthermore, the Roadmap recommends organizing workshops to raise awareness and facilitate the implementation of existing policies and standards, such as the NIRIPG standards in the road sector. Lastly, it advocates for incorporating a resilience-related nomenclature into sector budgets to incentivize investment in resilient infrastructure.

The successful implementation of the recommended measures necessitates mobilizing both technical and financial resources, alongside clearly defined responsibilities. To facilitate this, one of the recommendations of this Roadmap is to establish a government focal point and to identify potential technical and financial partners for each recommended measure.

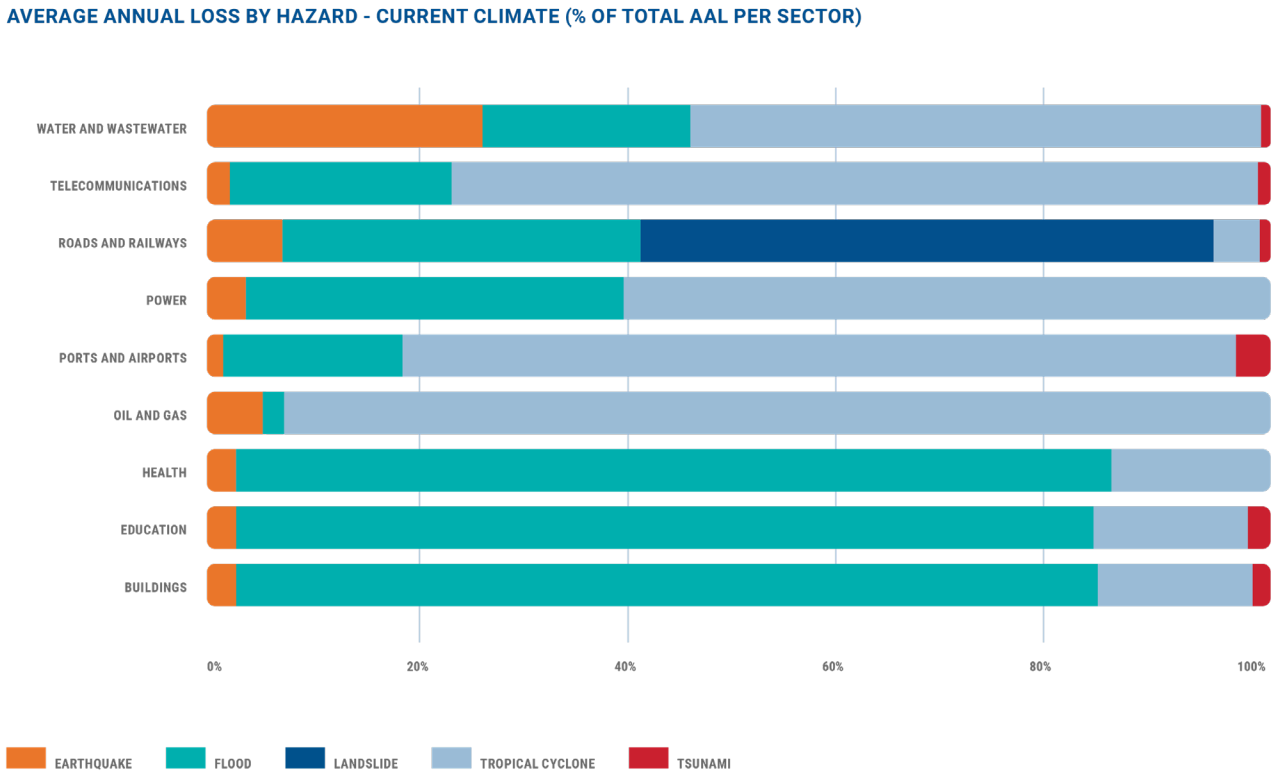
PART I.
APPROACH

The National Roadmap for Resilient Infrastructure in Madagascar is based on the global methodology developed by the United Nations Office for Disaster Risk Reduction (UNDRR) and the Coalition for Disaster Resilient Infrastructure (CDRI).[1] Using a participatory approach, this methodology aims to:

- **Highlight the vulnerabilities of infrastructure to a range of hazards** (e.g. climatic, geological and technological hazards), including by leveraging new data sources
- **Analyze interdependencies and cascading risks**, where the failure of one infrastructure component or system can lead to a domino effect, causing multiple systems to fail
- **Identify effective measures to enhance infrastructure resilience** and develop an action plan

Enhancing infrastructure resilience in Madagascar is paramount to reducing the considerable economic losses in this area, estimated at US$ 100 million per year (GFDRR, 2016).[2] The direct impact of infrastructure damage is compounded by indirect costs. Transport or energy service interruptions have a significant impact on the country's economic and social growth. For example, it is estimated that a medium-sized company outside the capital city loses almost a seventh of its sales every year due to poor-quality of the electric network

Figure 1. Average annual loss by hazard, current climate, Madagascar



Source: Global Infrastructure Resilience Index (GIRI), 2024

1. https://www.undrr.org/publication/global-methodology-infrastructure-resilience-review
2. Total direct losses caused by earthquakes, floods and tropical cyclones.

A. Critical Infrastructure

The first key element is to identify the critical infrastructure to be included in the analysis. Generally, they pertain to key infrastructure sectors, namely energy, transport, telecommunications and water, which play a systemic role in the country's functioning. In the case of Madagascar, it was agreed to add the education sector.

These sectors perform vital functions, ten of which were assessed as part of a crisis simulation exercise:

- Water supply
- Wastewater management
- Air cargo transport
- Rail cargo transport
- Road cargo transport
- Building and maintenance of ports and waterways
- Power generation
- Power transport
- Telecommunications service supply
- Education service supply

B. Hazard Profile

The second key element in this analysis is defining the type of hazards to be considered. The objective is to establish a list that includes the most significant—but not all—hazards, otherwise it would become impossible to perform an analysis. A list of 10 hazards was considered in the analysis:

Table 1. List of Hazards Considered in the Analysis

HAZARDS	IMPACTS
CYCLONES	Responsible for 85% of recorded losses (UNDRR, 2016), cyclone events are the costliest hazards causing up to US$87 million in losses on average each year. "On average and per cyclone season (November to April), 10 tropical disturbances occur in the Southwest Indian Ocean (SWIO) basin, of which 5 become cyclones"[3] (DGM et al., 2023).
FLOODS	Resulting from cyclones, high water runoff, rising sea levels, or heavy rains, floods are responsible for total direct losses of US$13 million on average each year (UNDRR, 2016). Floods lead to dike failures which affect homes, infrastructure as well as several other sectors (CPGU, DGM, 2019).
RISING SEA LEVELS	Variations in rainfall patterns affect water flow and level. This has implications for energy production and increases hydroelectric power generation costs. The temporal evolution of cumulative annual rainfall anomalies observed in Madagascar's six climate zones between 1961 and 2018 clearly suggests a significant drop of 15% to 20% in 58 years (Météo Madagascar, 2023).
VARIATIONS IN RAINFALL PATTERNS	Variations in rainfall patterns affect water flow and level. This has implications for energy production and increases hydroelectric power generation costs. The temporal evolution of cumulative annual rainfall anomalies observed in Madagascar's six climate zones between 1961 and 2018 clearly suggests a significant drop of 15% to 20% in 58 years (Météo Madagascar, 2023).

3. Météo Madagascar, 2023: Observed Climate Trends and Future Climate Change in Madagascar, 2023. Kotomangazafy Stephason F., Nirivololona Raholijao, Zo A. Rakotomavo, M. D. Leroux, F. Bonnardot]. General Directorate for Meteorology of Madagascar & Inter-regional Directorate of Météo-France for the Indian Ocean, La Réunion.

HEATWAVES	Heatwaves exacerbate the formation of cyclones and contribute to decreasing rainfall and variations in temperature and sea level. The temporal evolution of mean annual temperature anomalies observed over Madagascar's six climate zones between 1961 and 2018 has made it possible to anticipate that in 58 years, a warming of +0.75°C to +1.6°C could be observed (Météo Madagascar, 2023).
LANDSLIDES	Landslides have been occurring with increasing frequency over the last five years. Such an increase can be attributed to several factors, including rainwater drainage (high infiltration), degradation of drainage systems, unplanned urban sprawl and illegal construction activities in areas with steep slopes (over 45°).
EARTHQUAKES	Due to its gradual split from the African continent, Madagascar is subject to local seismic activities that are typically of low to moderate intensity. Seismic activities cause minimal losses, contributing to just 1% of direct annual losses (UNDRR, 2016) with an estimated annual average of US$1.3 million. The capital city, Antananarivo, bears the most significant risk, facing an estimated annual loss of US$870,000.
FIRES	One of Madagascar's main hazards, fires cause loss of life and infrastructure, particularly critical infrastructure such as homes, factory facilities and school buildings.
PANDEMICS	Pandemics are diseases that spread very rapidly and can cause deaths, as in the case of cholera, plague and Covid-19. The consequences include difficulties or disruption of access to essential services, which are especially felt in the WASH, health and logistics sectors.
CYBERATTACKS	Many existing critical infrastructure systems were designed and implemented before cyber threats became commonplace. As a result, they may present vulnerabilities that can be exploited by cyber attackers to cause service interruptions.

C. Economic Linkages

The third element of this analysis is the linkages between infrastructure services and key sectors of the economy, which provide further insight into the importance of the resilience of these services. Madagascar presents a paradox of rich natural resources juxtaposed with major infrastructural challenges. The country is struggling with low and fluctuating GDP per capita, which has remained below US$500 since 1980 (World Bank, 2024), thus reflecting the structural limitations of its economy. Among the greatest obstacles to development is the limited coverage of the electricity network, with only around 15% of the population having access to electricity (World Bank, 2023). This situation severely impedes the country's ability to industrialize its key sectors, especially the dominant agropastoral sector that sustains 80% of the workforce (World Bank, 2023). This sector, although central to the economy, remains largely oriented towards subsistence farming, producing staples like rice, vanilla, coffee, spices and lychees[4] (FAO, 2024). At the same time, the mining sector, which exploits resources such as nickel, cobalt, chromium, titanium and heavy metals, is contributing significantly to GDP and exports, with large-scale projects such as Ambatovy, Sherritt or QMM (World Bank, 2024). Box 1 provides a summary of the country's main economic sectors covered by the analysis. The growth and modernization of these sectors are impeded by a lack of infrastructure, particularly in energy and transport, and the vulnerability of infrastructure to climate hazards.

A sound understanding of the respective importance of infrastructure systems for key sectors of the economy is essential to prioritizing actions. This understanding allows informed decision-making, especially with regard to the prioritization of investments and strategies aimed at enhancing the resilience of critical infrastructure. Table 1 below highlights the relationship and degree of significance of infrastructure services to the economic sectors selected for analysis. The table suggests that priority should be given to the road transport and water sectors in terms of economic impact, considering their critical importance to many key sectors of the economy.

4. FAOSTAT / https://www.fao.org/faostat/en/#country/129

Table 2. Critical Functions and Economic Sectors

Note: Scores range from 0 to 5 (0 indicates a very weak relationship, while 5 indicates an extraordinarily strong relationship)

	ECONOMIC SECTORS										
CRITICAL FUNCTIONS OF INFRASTRUCTURE	Agriculture	Mining industry	Textile	Construction	Tourism	Trade	Financial services	Public administration	Health	Education	Score (0 to 1)
Water supply	5	5	4	5	4	3	1	1	5	3	0.74
Wastewater management	3	5	4	5	4	2	0	1	5	5	0.67
Air cargo and passenger transport	1	1	2	1	5	3	3	4	3	1	0.47
Rail cargo and passenger transport	1	1	0	2	1	3	0	0	0	1	0.21
Road cargo and passenger transport	4	3	4	4	4	5	3	2	4	4	0.75
Building and maintenance of ports and waterways	3	4	4	4	2	5	3	2	2	1	0.62
Power generation	1	4	4	3	3	3	5	4	3	2	0.60
Power transport	1	4	4	3	3	3	5	4	3	2	0.60
Telecommunications service supply	0	2	3	1	3	1	5	4	2	2	0.40
Education services supply	1	1	1	1	1	2	2	4	3	5	0.40

Source: Authors, data collected during workshops held at steps 3 and 4 of project.

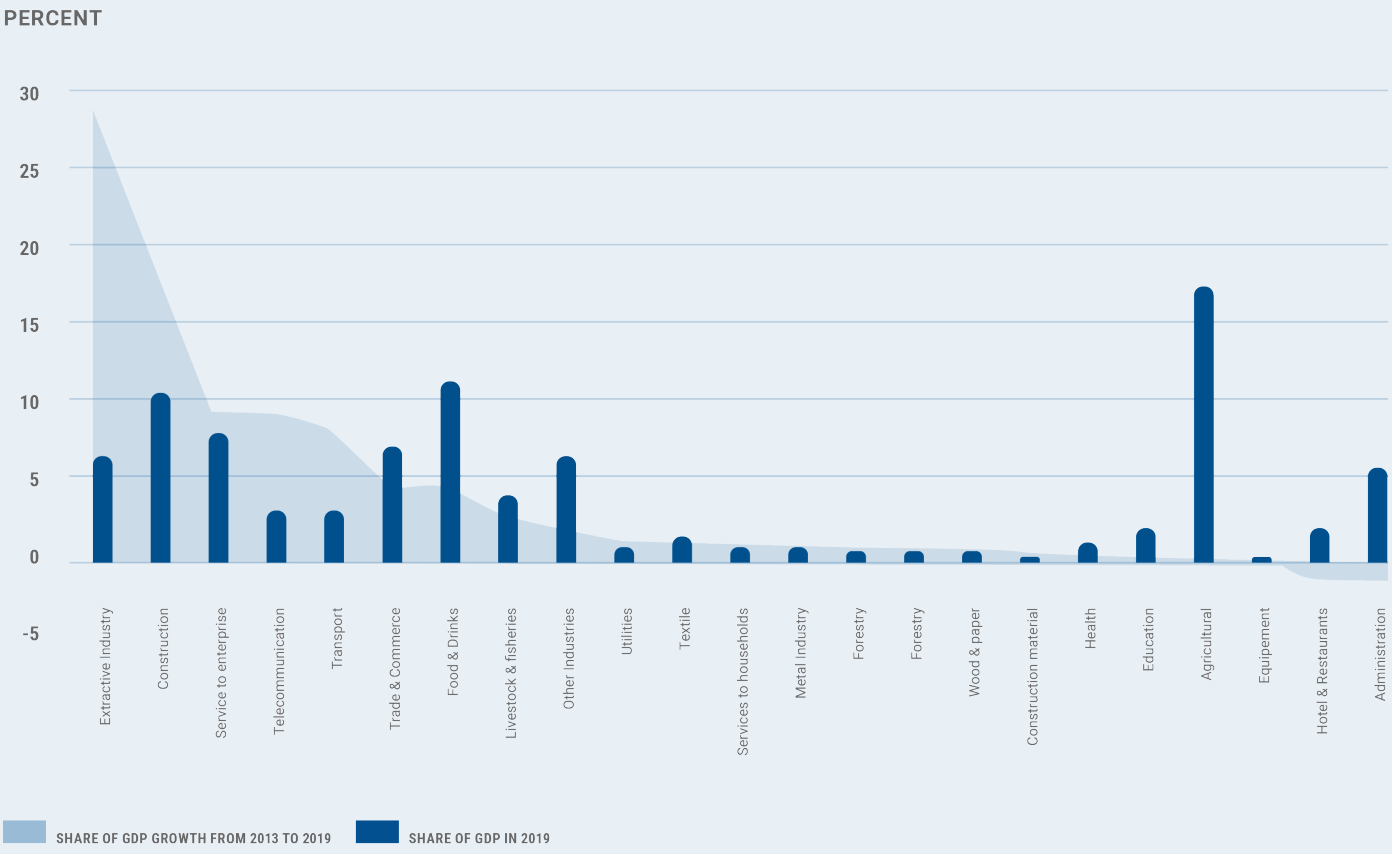
BOX 1. OVERVIEW OF MADAGASCAR'S ECONOMY

The following sectors play a significant role in the country's economy:

- **Agriculture:** Madagascar's economy is rooted in agriculture, fisheries and forestry. These sectors employ over 88% of the working population (INSTAT, 2022). Although agriculture is the predominant sector, it accounts for only 25% of Madagascar's GDP and 37% of exports due to a number of challenges, including a lack of inadequate infrastructure (INSTAT, 2022; World Bank 2024).
- **Extractive industry:** This sector employs only 0.3% of the workforce in Madagascar (INSTAT, 2022). Conversely, extractive industry has a disproportionately large impact on the country's economy, with a contribution of 5.19% to GDP (INSTAT, 2022), largely driven by the robust performance of mineral exports (MEF, 2022).
- **Textile:** The textile industry employs 3.8% of the workforce and contributes 1.05% to GDP (INSTAT, 2022). The sector has shown an impressive 24% growth in exports growth in 2022 and is a significant source of employment and economic expansion (MEF, 2022).
- **Construction and public works:** Employing 0.8% of the workforce, the construction and public works sector is a pillar of socio-economic development, contributing 12.6% to Madagascar's GDP (INSTAT, 2022).
- **Tourism:** Employing 0.5% of the workforce, the tourism sector is a driver of Madagascar's economic growth, accounting for 1.72% of GDP and showing a notable increase in tourist arrivals in 2022 (INSTAT, 2022; MEF, 2023).
- **Trade:** It is a key sector employing 2.6% of the workforce, contributing 11.14% of GDP and supporting a wide range of economic activities (INSTAT, 2022).

- **Financial services:** Although still developing, this sector is a significant contributor to Madagascar's economy, providing not only 3.8% of GDP but also notable employment opportunities that support broader economic growth.
- **Public administration:** Employing 0.3% of the workforce, public administration is vital to the economy, accounting for 5.62% of the GDP and supporting economic activities in other sectors.
- Health: Employing 0.5% of the population, the health sector accounts for 1.26% of Madagascar's GDP. The sector plays a pivotal role in public health and social support.
- **Education:** The education sector, which employs 0.3% of the workforce, accounts for 2% of the country's GDP, which corresponds to expenditure on education and educational infrastructure.

Figure 2. Sectoral Shares of GDP Growth



Source: World Bank - 2022 Systematic Country Diagnostic Update for Madagascar

D. Principles for Resilient Infrastructure

The fourth element of the approach is applying the Principles for resilient infrastructure to examine and assess the resilience of the country's infrastructure systems. Developed through extensive collaboration with around 100 governments and international experts, these principles are an international benchmark and the basis for the recommendations advocated in this Roadmap.

Political decision-makers can adopt these principles at different stages of the infrastructure lifecycle. Generally, the lifecycle stages are as follows: before construction (strategic planning and project prioritization), during implementation (design, procurement and construction) and during operation (operation and maintenance).

To build the Roadmap, the next chapters of this Roadmap examine whether resilient practices, as defined in the Principles, are already in place in the country. The Roadmap subsequently identifies the practices that should be recommended based both on the risks the country is facing and local circumstances. To this end, the principles were reviewed one by one during a workshop with key stakeholders in Madagascar. Appendix IV presents the dashboard with the detailed findings of this review. The key lessons learned from the review are presented below.

PRINCIPLE 1 (CONTINUOUSLY LEARNING)

The goal of this principle is to develop and update understanding and insights into infrastructure resilience. The following table illustrates how to implement this principle.

LIFECYCLE STAGES	EXAMPLES OF INTERVENTIONS (the number in brackets refers to the sub-actions included in each Principle – see publication for further information)[5]
PLANNING	Set up a system to ensure that lessons learned from past disasters are disseminated to inform future planning (P1.3).
IMPLEMENTATION / CONSTRUCTION	Review and validate climate and disaster scenarios used for the preparation and design of infrastructure projects (P1.1)

5. https://www.undrr.org/publication/principles-resilient-infrastructure and https://www.undrr.org/publication/handbook-implementing-principles-resilient-infrastructure

OPERATION / MAINTENANCE	Strengthen monitoring, detection and early warning systems to minimize disruption to essential services (P1.2.) Require operators to perform regular stress tests to identify vulnerabilities and opportunities for improvement (P1.4)

The review suggests that this principle is only moderately implemented in Madagascar, and should therefore be a priority. For example, the country has an early warning system in place, but it is not comprehensive and does not cover all sectors, nor the whole country. There are also contingency plans, but these are still based on historical data. Crisis control and simulation systems are also inadequate.

PRINCIPLE 2 (PROACTIVELY PROTECTED)

The goal of this principle is to enhance preparedness and response to hazards/threats. The following table illustrates how to implement this principle.

LIFECYCLE STAGES	EXAMPLES OF INTERVENTIONS (the number in brackets refers to the sub-actions included in each Principle – see publication for further information)[6]
PLANNING	Draw up a list of interventions aimed at improving safety (P2.1) Identify critical components of national infrastructure and prioritize them for necessary upgrades (P2.2.) Set up cross-sectoral planning committees to ensure that efforts are coordinated, and cascading risk data are shared across infrastructure sectors (P2.3)
IMPLEMENTATION / CONSTRUCTION	Require that infrastructure design include safe-to-fail solutions (e.g., plan backup solutions for energy supply and design control systems for hazardous materials) (P2.5) Require resilience assessments and interdependency analyses in infrastructure projects (P2.3) Require long-term maintenance plans as part of the initial approval process for infrastructure projects (P2.7) Ensure that project appraisal adopts a long-term approach and considers life-cycle costs, including those related to potential disasters (P2.8)
OPERATION / MAINTENANCE	Strengthen the capacity of local operators to cope with disruptions (e.g. drills) (P2.4). Ensure that critical services can be provided at different scales: national, regional and local, and make redundancy operational for smaller-scale solutions (P2.6). Set up funds dedicated specifically to maintenance (P2.7).

A great deal of work has been done in Madagascar to develop hazard-adapted infrastructure standards, but these are not always respected or applied. Quality control remains a challenge, especially for projects that are not funded by major international donors. Some projects also focus on safety. For example, there is talk of relocating LP Madagascar, which manages fuel storage in the country, for safety reasons. In terms of redundancy systems, it should be noted that due to the absence of a water network connection, many households (70%) rely on deliveries by truck, which in turn depend on the condition of the roads. Finally, there is a considerable lack of funding for infrastructure maintenance.

6. https://www.undrr.org/publication/principles-resilient-infrastructure and https://www.undrr.org/publication/handbook-implementing-principles-resilient-infrastructure

PRINCIPLE 3 (ENVIRONMENTALLY INTEGRATED)

The goal of this principle is to work in a positively integrated way with the natural environment. The following table illustrates how to implement this principle.

LIFECYCLE STAGES	EXAMPLES OF INTERVENTIONS (the number in brackets refers to the sub-actions included in each Principle – see publication for further information)[7]
PLANNING	Promote the use of environmental information in infrastructure planning (P3.3)
IMPLEMENTATION / CONSTRUCTION	Conduct audits to monitor the environmental impact from infrastructure systems (P3.1) Include a cost-benefit analysis of environmental solutions in comparison to other conventional or grey alternatives in project preparation documents (P3.2) Identify local resources and encourage their use for infrastructure projects through selection criteria in procurement process (P3.5)
OPERATION / MAINTENANCE	Lay down policies and regulations to ensure contractors and operators maintain the surrounding natural environment to reduce threat of disruption to critical services (P3.4).

The analysis conducted in Madagascar identifies two critical weaknesses in this area, namely the lack of environmental information at the project planning stage and the inadequate use of locally available resources. Regarding the latter issue, public procurement requirements are generally donor-driven rather than sector-specific.

As far as environmental regulations are concerned, provisions do exist, but they are not always effectively applied. For example, the Office National pour l'Environnement (National Environment Office, ONE) is responsible for categorizing natural surroundings, with specific environmental management requirements. ONE's approval is required for the implementation of infrastructure projects according to these categories.

Finally, each sector is gradually integrating Nature-based Solutions (NbS) for disaster risk management. For example, Antananarivo's Flood Protection Authority (Autorité pour la Protection contre les Inondations de la Plaine d'Antananarivo, APIPA) has already considered the use of green infrastructure, such as planting vetiver along canals and dikes, for flooding mitigation. Other sectors, such as public works, are also involved in supporting mangrove reforestation to mitigate the risks of flooding and marine erosion in coastal areas. Nevertheless, the application of these best practices remains a challenge.

PRINCIPLE 4 (SOCIALLY ENGAGED)

The goal of this principle is to develop active engagement, involvement and participation across all levels of society. The following table illustrates how to implement this principle.

7. https ://www.undrr.org/publication/principles-resilient-infrastructure and https ://www.undrr.org/publication/handbook-implementing-principles-resilient-infrastructure

LIFECYCLE STAGES	EXAMPLES OF INTERVENTIONS (the number in brackets refers to the sub-actions included in each Principle – see publication for further information)[8]
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) Promote education about resiliency, taking advantage of formal education programs and local media, depending on the target audience (P4.2)
IMPLEMENTATION / CONSTRUCTION	Ensure contractors and operators include appropriate channels for emergency communications in project design (P4.1)
OPERATION / MAINTENANCE	Define obligations for infrastructure sectors to adopt incentive policies or strategies for demand reduction, shifting or avoidance. (P4.3) Encourage operators to develop community engagement programs (P4.4)

The analysis conducted in Madagascar underscores the gap in infrastructure resilience training, which is essential for enhancing community engagement and should be a priority for the future. Furthermore, the involvement of community members in infrastructure decisions remains limited in urban areas, whereas it is significant in rural areas. Finally, messages about infrastructure service disruption are generally understood, but not always adhered to due to a lack of trust.

PRINCIPLE 5 (SHARED RESPONSIBILITY)

The goal of this principle is to share information and expertise to gain the benefits of a more coordinated approach. The following table illustrates how to implement this principle.

LIFECYCLE STAGES	EXAMPLES OF INTERVENTIONS (the number in brackets refers to the sub-actions included in each Principle – see publication for further information)[9]
PLANNING	Engage with stakeholders and experts to select or devise information-sharing standards and incorporate them into relevant regulations and law (P5.1) Collaborate with stakeholders and experts to encourage multi- and trans-sectoral collaboration for enhanced infrastructure resilience (P5.2) Develop and formalize security regulations for data sharing (P5.5)
IMPLEMENTATION / CONSTRUCTION	Collect construction and operational data formatted in compliance with relevant standards (P5.1)
OPERATION / MAINTENANCE	Create and utilize data-sharing platforms with sufficiently robust communication channels to disseminate information to relevant stakeholders effectively (P5.4). Collate and share data rapidly during disruptions to enable a coordinated response (P5.4).

Some exchange platforms in Madagascar have implemented mandated information sharing between operators from different sectors in the event of shocks. These sectors also maintain a culture of collaborative management and hold meetings at least twice a year. Data sharing remains fairly

8. https ://www.undrr.org/publication/principles-resilient-infrastructure and https ://www.undrr.org/publication/handbook-implementing-principles-resilient-infrastructure
9. https ://www.undrr.org/publication/principles-resilient-infrastructure and https ://www.undrr.org/publication/handbook-implementing-principles-resilient-infrastructure

limited due to the sensitivity of the content and is strongly governed by non-disclosure agreements. A national risk atlas, developed with the World Bank, is available, however sector-specific data input is almost non-existent.[10]

PRINCIPLE 6 (ADAPTIVELY TRANSFORMING)

The goal of this principle is to adapt and transform to changing needs. The following table illustrates how to implement this principle.

LIFECYCLE STAGES	EXAMPLES OF INTERVENTIONS (the number in brackets refers to the sub-actions included in each Principle – see publication for further information)[11]
PLANNING	Monitor demand and ensure that capacity can meet expected future demand either through demand reduction or increasing capacity (P6.4).
IMPLEMENTATION / CONSTRUCTION	Design systems according to local resources and capacity (P6.1) Provide designs that allow usage to be measured and capacity to be adapted to future changes (P6.2)
OPERATION / MAINTENANCE	Monitor compliance with override capacity requirements, allowing for human assessment, and report on non-compliance (P6.5).

While Madagascar has a contingency plan and a plan for critical services continuity in the event of a disaster, the challenge lies in their implementation. For instance, emergency-related training and emergency drills are not conducted at community level.

Infrastructure is also poorly aligned with locally available skills and resources. The energy sector, for instance, struggles with outdated machinery and a lack of suitable spare parts, which involves either adapting existing components or enduring lengthy delays to source the correct ones.

10. https ://documents1.worldbank.org/curated/ru/262521494235299571/pdf/114366-FRENCH-WP-PUBLIC-drp-madagascar-fr.pdf
11. https ://www.undrr.org/publication/principles-resilient-infrastructure and https ://www.undrr.org/publication/handbook-implementing-principles-resilient-infrastructure

E. Cross-cutting Recommendations

The following recommendations are derived from the above analysis and from a series of consultations.
(Please note that the list of technical and financial partners is not intended to be exhaustive, but rather indicative, and the possibility of support from these partners remains to be confirmed).

Table 3. Cross-cutting recommendations

RECOMMANDATIONS	FOCUS AREAS	RELATED PRINCIPLES	ENTITIES INVOLVED	POTENTIAL TECHNICAL AND FINANCIAL PARTNER	PRIORITY	TIMELINE
Appoint a focal point to monitor the implementation of these recommendations.	4. Governance and coordination	P1.3	CPGU (Lead)		High	Short-term
Organize informational workshops on existing policies, standards and regulations (e.g. NIRIPG standards in the road sector).	5. Policies, Standards and Regulations	P2.1	CPGU (Lead)	UNDP, World Bank, USAID, UNDRR, UNITAR, UNOPS	Moderate	Short-term
Acquire the resources needed for infrastructure monitoring and evaluation at national level, including imagery acquisition (UAV, satellite, LIDAR, etc.), analysis tools (ARCGIS, QGIS, MicroStation, ENVI) as well as monitoring tools (Power BI).	1. Data, Monitoring & Evaluation	P1.2, P5.1	CPGU (Lead), PNRRC, MDPT, UGD, relevant ministries	UNDP, World Bank, USAID, UNOSAT	Moderate	Short-term
Include a nomenclature on infrastructure resilience in each sector's budget to spur investment.	5. Policies, Standards and Regulations	P2.7, P2.8	MEF (Lead), relevant ministries	IMF, World Bank, UNDRR, UNDP	High	Short-term
Raise awareness of the public about its role in safeguarding the provision of critical services, and in reinforcing infrastructure security measures against acts of theft and vandalism.	4. Governance and coordination	P4.1	BNGRC (Lead), MCC	Critical service providers (companies or agencies)	Moderate	Short-term
Implement a digital database management system for infrastructure resilience within the PNRRC and digitalize construction standards monitoring and control in order to enhance proactive utilization of the collected data. This includes building the capacity of ministry technicians, allocating adequate material and financial resources, and identifying a focal point in each relevant ministry to ensure effective data management.	1. Data, Monitoring and Evaluation 2. Capacity building	P5.1, P5.4	CPGU (Lead), All relevant ministries	Development Banks, UNDRR, GRMA, UNDP, USAID-WASH	High	Medium-term

RECOMMANDATIONS	FOCUS AREAS	RELATED PRINCIPLES	ENTITIES INVOLVED	POTENTIAL TECHNICAL AND FINANCIAL PARTNER	PRIORITY	TIMELINE
Develop a comprehensive plan detailing the action plans of each sector with regard to the provision of critical infrastructure services in emergency situations.	5. Policies, Standards and Regulations	P1.1, P1.3 et P1.4	BNGRC (Lead), CPGU, PNRRC	Humanitarian partners, UNOPS, UNDRR	High	Medium-term
Organize regular stress tests to assess the extent to which each sector is integrating hazards and 3Bs (Build Back Better) concepts (and include the health and agriculture sectors).	1. Data, Monitoring and Evaluation	P1.4	CPGU (Lead), PNRRC	CDRI, UNDRR, UNOSAT, UNITAR,	Moderate	Medium-term
Strengthen the capacity of staff in the sectors considered in this analysis to use early warning and infrastructure monitoring systems, by organizing monthly experience-sharing meetings, training sessions and refresher workshops on critical services continuity during and after risk materialization.	2. Capacity building	P1.2, P1.3, P1.4 et P6.2	PNNRRC (Lead), BNGRC, CPGU, All ministries	CDRI, UNDRR, UNOSAT, Start Network, UN Agencies, Red-Cross, Research Centers (e.g., CERED)	Moderate	Medium-term
Update infrastructure resilience standards and explicitly introduce infrastructure resilience concepts in sectors where standards exist. Develop new specific standards in sectors where they are lacking, especially for telecommunications, energy and rail transport.	5. Policies, Standards and Regulations	P2.1	CPGU (Lead), MEH, MDPT, MTM, MTP	UNOPS, World Bank, European Union, UN System, UNDRR	High	Medium-term
Set up a formal communication mechanism between private operators and relevant ministries to ensure that feedback on technical issues, repairs and troubleshooting is systematically provided to relevant authorities.	4. Governance and Coordination	P5.2, P5.3	BNGRC (Lead), private operators, relevant ministries	Development Banks, UNOPS, UNDRR	High	Medium-term
Enhance inter-ministerial coordination and consultation in the implementation and planning stages, by organizing quarterly technical meetings and leveraging existing land use planning tools and other sectoral documents.	4. Governance and Coordination	P3.1	CPGU (Lead), MEF	Development Banks, IMF, UN Agencies	Moderate	Medium-term
Develop legal texts and notes supporting the prioritization of local resources wherever possible.	5. Policies, Standards and Regulations	P6.1	CPGU (Lead), All relevant ministries	UNOPS, World Bank	Moderate	Medium-term
Encourage Public-Private Partnerships (PPPs) in the construction of resilient infrastructure, supported by a clear legal and regulatory framework and improved transparency, governance and financial incentives.	3. Infrastructure Projects	P2.8	CPGU (Lead), Relevant ministries	World Bank, AfDB, UNDP, UNDRR, CDRI	High	Long-term
Build the capacity of decision-makers and members of the technical environmental assessment committee as regards best practices related to Nature-Based Solutions (NbS) and new environmental assessment techniques for infrastructure, through the implementation of targeted training programs.	2. Capacity Building	P3.3	Ministry of Environment	NGO, WWF, Club Vintsy, Medias, UN Agencies	Moderate	Long-term
Develop a data-sharing charter to build trust and encourage data-holding institutions to participate in data exchange.	1. Data, Monitoring and Evaluation	P5.5	CPGU (Lead), BNGRC, Relevant ministries	UNDRR	High	Long-term

RECOMMANDATIONS	FOCUS AREAS	RELATED PRINCIPLES	ENTITIES INVOLVED	POTENTIAL TECHNICAL AND FINANCIAL PARTNER	PRIORITY	TIMELINE
Share best practices on community interventions aimed at strengthening infrastructure resilience (e.g. dike maintenance) by organizing annual conferences and workshops at the national level.	2. Capacity Building	P1.3, P1.4 P.4.4, et P6.5	BNGRC (Lead), CPGU	UN Agencies	Moderate	Long-term
Strengthen the capacities of key members of the infrastructure thematic group through exchanges and sharing of experience at international and inter-regional levels.	2. Capacity Building	P1.3	PNRRC	CDRI, UNDRR, UNOSAT, UNITAR, World Bank	High	Long-term

Photo by Davidson Free Media: https://www.pexels.com/photo/brown-dock-on-the-shore-during-night-time-3880176/

Photo by Davidson Free Media https/www.pexels.comphotoman-riding-a-boat-3880179

PART II.
CROSS-SECTORAL ANALYSIS

To deepen the analysis of infrastructure resilience in the country, it is important to consider the cross-sectoral level, as it plays a key role in terms of coordination. Disaster resilience efforts are often fragmented, with different sectors focusing solely on their specific responsibilities, without taking full account of wider implications. A cross-sectoral approach helps to avoid such issues and improves coordination and cooperation, while ensuring that resources are utilized more efficiently.

A. Political and Institutional Framework

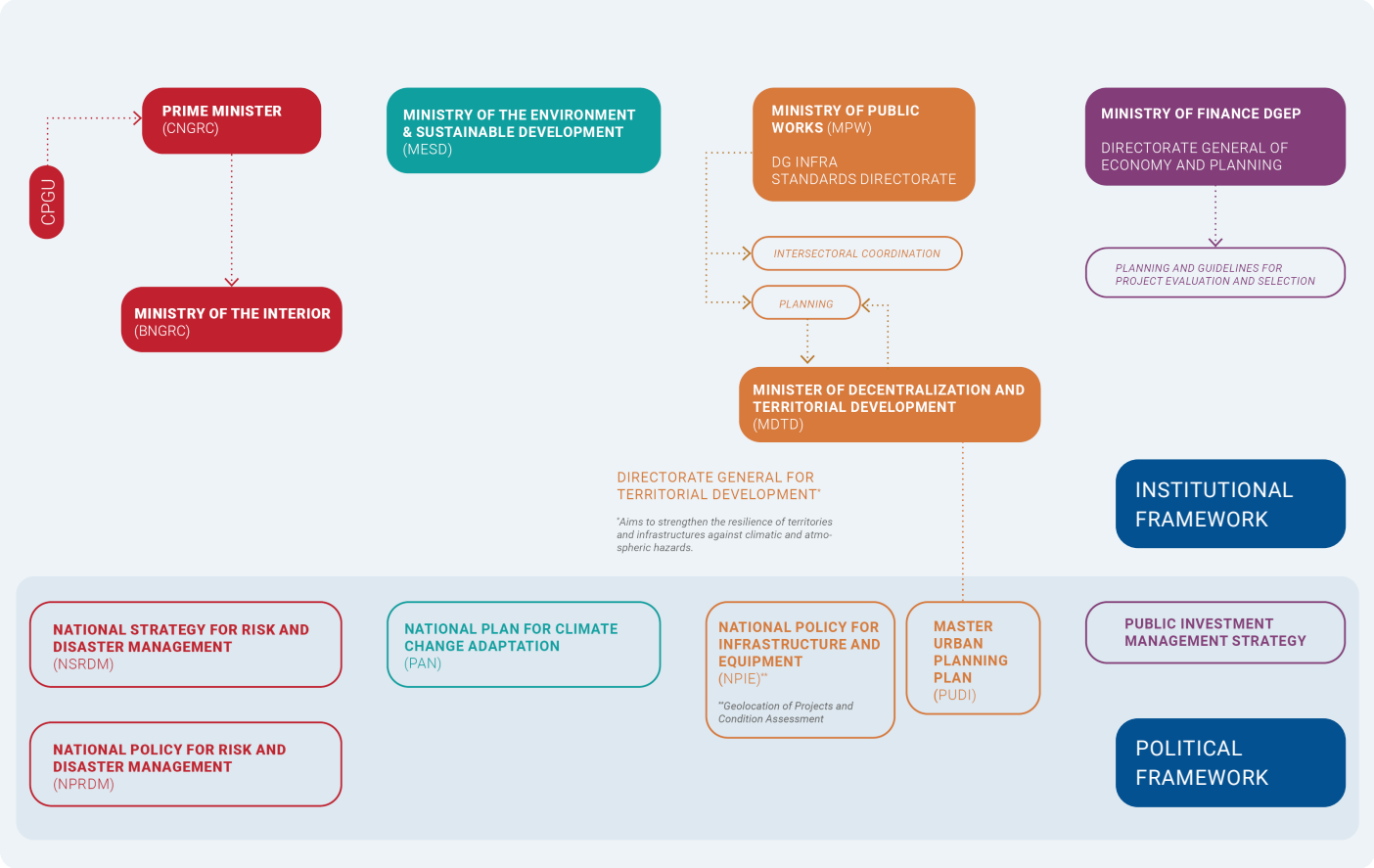
A wide array of national actors plays a role in building resilient infrastructure. The four broad categories encompassing these players include (i) disaster risk reduction and management, (ii) climate change adaptation, (iii) construction and planning, and (iv) investment. The figure below provides an overview of these players while Table 3 gives further details on institutions involved in disaster risk reduction and management.

These national players have developed a substantial number of cross-cutting policies with a direct or indirect impact on infrastructure resilience. The integration of disaster risk components into these cross-cutting policies facilitates collaboration, cooperation and coordination between different sectors and stakeholders. It fosters joint planning, information sharing and resource allocation to address common vulnerabilities and enhance overall resilience.

Madagascar's key policy documents contain several measures aimed at enhancing infrastructure resilience. The country has recently set up a robust legislative framework that promotes a multi-hazard and multi-sectoral approach to risk reduction and management. The national disaster risk reduction policy (Politique Nationale de Gestion des Risques de Catastrophes) establishes specific regulations, such as Decree No. 2019-1957, for hazard-resistant buildings. Furthermore, the National Adaptation Plan (NAP) puts an emphasis on the integration of infrastructure resilience and land use planning.

There are, however, gaps in conducting regular risk assessment and identifying critical entities, despite the proposal for the integration of a Strategic Environmental and Social Assessment (SESA) in the NAP. Strengthening these processes is essential for enhancing the effectiveness of infrastructure resilience policies.

Figure 3. Overview of the Institutional and Policy Framework related to Infrastructure Resilience



Source : Authors

Table 4. Institutional Mechanism Dedicated to DRR/DRM

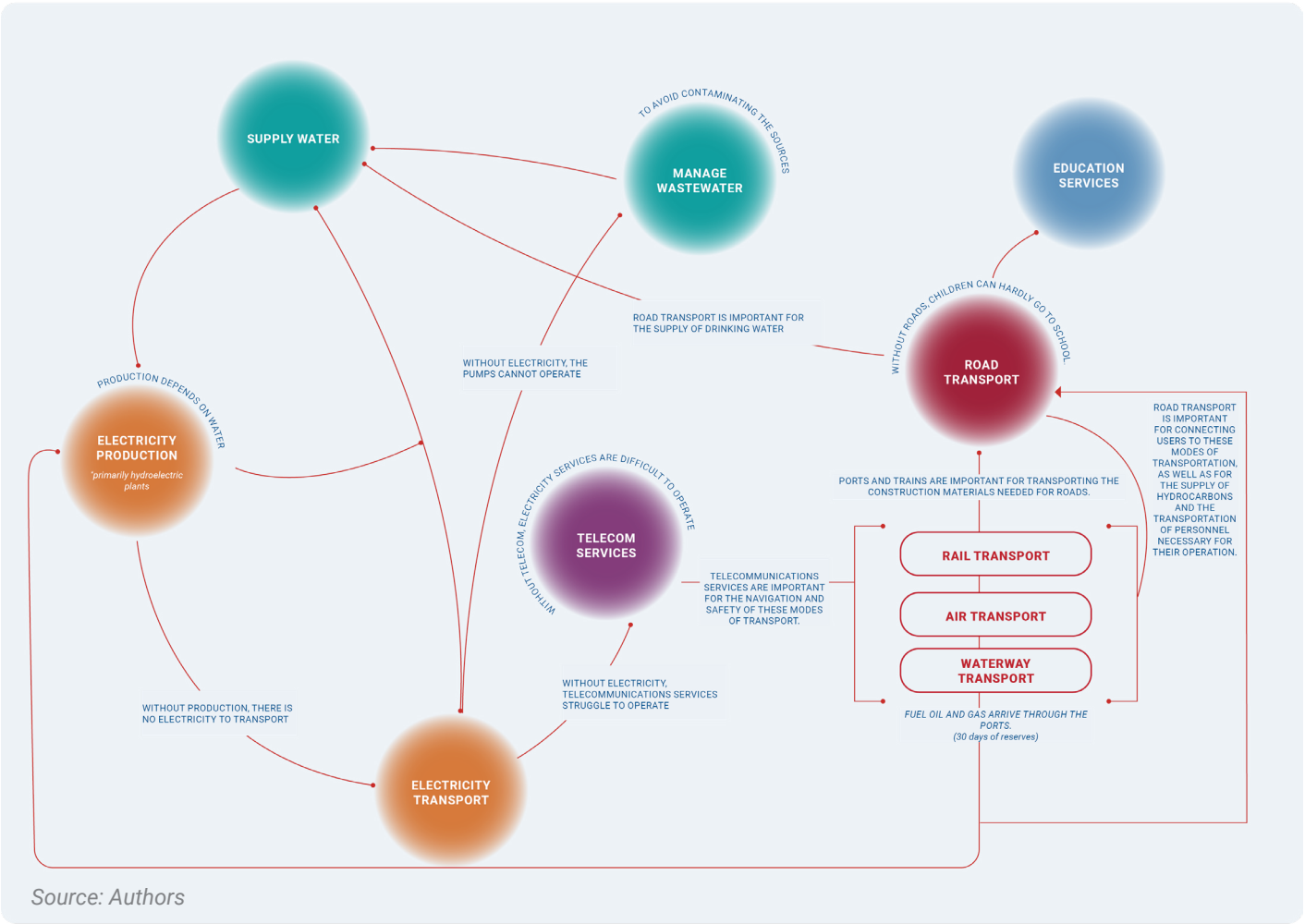
STRATEGIC LEVEL	
CONSEIL NATIONAL DE GESTION DES RISQUES ET CATASTROPHES (NATIONAL COUNCIL FOR RISK AND DISASTER MANAGEMENT) (CNGRC)	**Structure for consultation and decision-making at national level,** under the responsibility of the Prime Minister. It is responsible for the strategic design, development, supervision and updating of the National Strategy for Risk and Disaster Management (Stratégie Nationale de Gestion des Risques et des Catastrophes, SNGRC) and its action plan, and for promoting the integration of DRR in sectoral development policies at all levels.
CELLULE DE PRÉVENTION ET D'APPUI À LA GESTION DES URGENCES (EMERGENCY PREVENTION AND MANAGEMENT UNIT) (CPGU) *Since 2016*	**Standing technical support structure attached to the Prime Minister's Office and supporting the CNGRC,** it provides technical support to the Prime Minister and to the Ministry of Interior, as well as sectoral support in DRM/DRR in Madagascar.
PLATEFORME NATIONALE DE RÉDUCTION DES RISQUES DE CATASTROPHE (NATIONAL PLATFORM FOR DISASTER RISK REDUCTION) (PNRRC) *Since 2022*	**A forum for exchange and sharing between all DRR stakeholders.**

OPERATIONAL LEVEL	
BUREAU NATIONAL DE GESTION DES RISQUES ET CATASTROPHES (NATIONAL RISK AND DISASTER MANAGEMENT OFFICE) (BNGRC) *Since 2006*	**Central operational structure attached to the Ministry of Interior, with branches planned to extend to the territorial level. Its mandate is to coordinate risk and disaster management at a national level.** This responsibility encompasses preparedness, strategic planning and humanitarian response.
COMITÉ DE RÉFLEXION DES INTERVENANTS AUX CATASTROPHES (DISASTER RESPONSE COORDINATION COMMITTEE) (CRIC) *Since 1996*	**Ad hoc crisis structure organized into eight sectoral clusters.** A coordination mechanism has also been set up with development partners in the event of a humanitarian crisis.

B. Interdependencies and cascading risks

Recognizing the interconnected nature of infrastructure systems is key to the analysis of infrastructure resilience. For instance, a power outage may affect communication, transportation, and water supply systems. Power outages can also halt the operation of pumping equipment that keeps floodwaters under control, as it has already previously occurred in and around Antananarivo plain and its surrounding areas. A thorough understanding of these interdependencies makes it possible to prevent the chain of failures and to maintain the continuity of critical services to the population. Figure 4 below shows the main dependencies highlighted by the various stakeholders consulted in Madagascar.

Figure 4. Simplified Diagram of Interdependencies

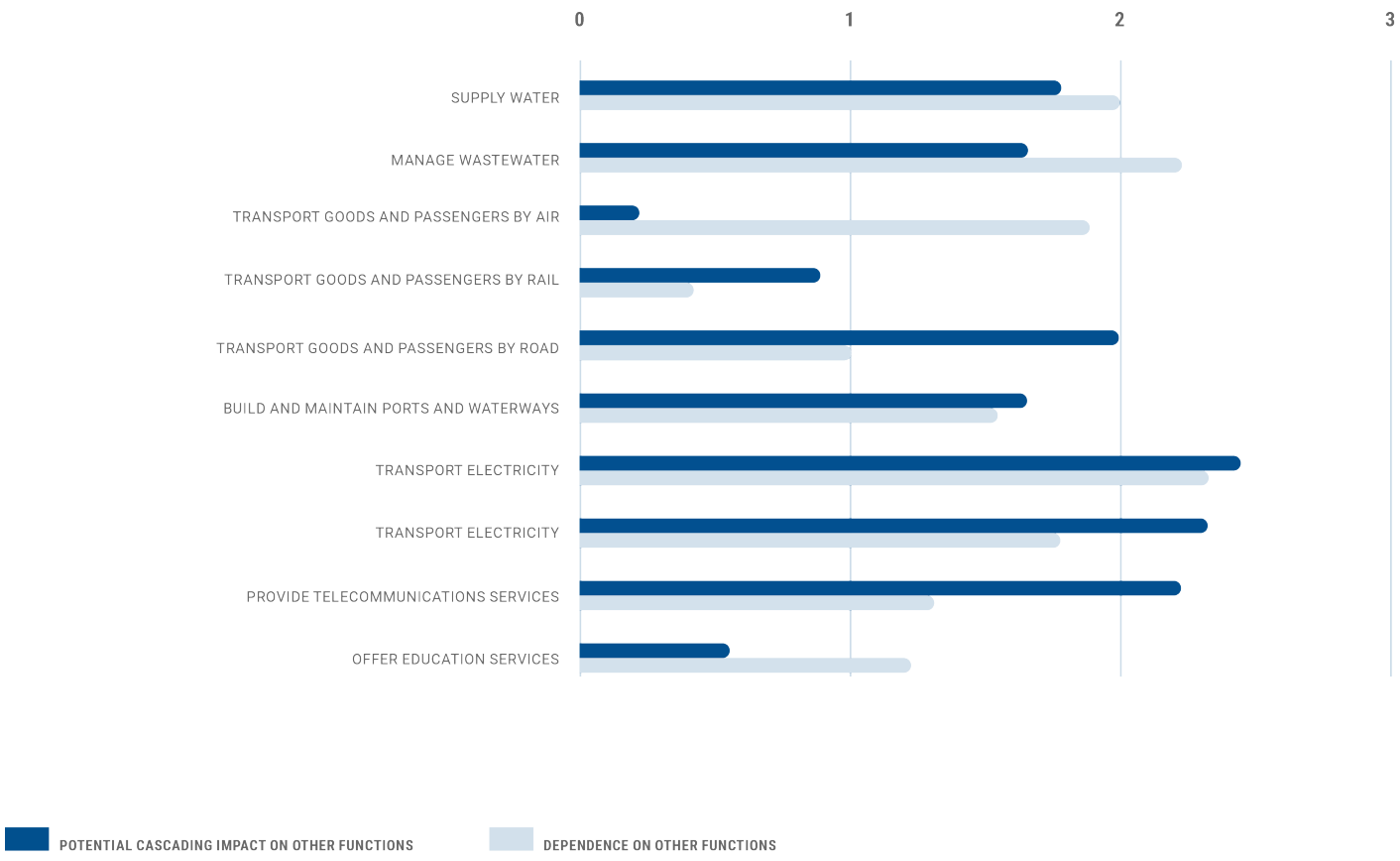


Source: Authors

Once the interdependencies have been identified, it is possible to measure the risks of cascading failures. This can be achieved using the stress testing tool of the United Nations Office for Disaster Risk Reduction (UNDRR). This tool simulates various crisis scenarios and assesses the potential impact on different infrastructure sectors. It helps decision-makers understand vulnerabilities and analyze domino effects to devise more effective strategies for disaster prevention and mitigation.

Figure 5 shows the extent to which some functions are highly dependent on others, but also the extent to which each function presents a different risk of creating cascading disruptions. For instance, telecommunications and power generation, with scores between 2 and 3, are identified as having a higher likelihood of triggering cascading failures than air transport or education services (scores between 0 and 1). Wastewater management, while not having as high a cascading effect, also scores above 2 for dependency, indicating greater vulnerability to disruption of other infrastructure. Figure 5 presents a simplified diagram of these interdependencies.

Figure 5. Interdependency of Functions and Cascading Effects



Source: Authors, data collected during workshops held at steps 3 and 4 of the project.

Photo by Megane SSu: https://www.pexels.com/photo/children-near-abandoned-house-in-africa-countryside-7506103/

PART III.
SECTORAL VULNERABILITIES AND RESILIENCE

An in-depth analysis by infrastructure sector is necessary to complement the cross-sectoral analysis and cross-cutting recommendations. This analysis allows for the identification of vulnerabilities and disaster risk exposure for each of the critical infrastructure functions. It also facilitates the development of targeted measures to enhance resilience.

Depending on their characteristics, the various infrastructure sectors are more or less vulnerable to certain hazards. This is illustrated in Table 3, which summarizes the outcome of consultations conducted in Madagascar. A high score indicates that the hazard poses a significant risk to the infrastructure function under review. The rationale behind each rating is explained in more detail in Appendix I.

Table 5. Representation of Risks Posed by Different Hazards to Infrastructure Functions

HAZARDS VS. CRITICAL FUNCTIONS OF INFRASTRUCTURE		Floods	Cyclones	Rising sea levels	Heatwaves / Drought	Landslides	Earthquakes	Fires (urban, forest or bush fires)	Pandemics	Cyber attacks	Construction/ Structural deficiencies
WATER	Water supply	5	5	5	5	0	2	4	1	1	4
	Wastewater management	5	5	5	3	0	2	4	1	1	4
TRANSPORT	Air cargo and passenger transport	2	5	0	0	0	0	0	5	2	3
	Rail cargo and passenger transport	1	3	0	0	4	1	0	1	0	2
	Road cargo and passenger transport	5	5	2	2	5	1	0	4	0	4
	Building and maintenance of ports and waterways	3	3	3	1	2	1	1	2	1	2
ELECTRICITY	Power generation	3	3	0	3	1	1	2	0	2	5
	Power transport	3	5	0	0	3	1	2	0	2	2
TELECOM	Telecommunications service supply	2	4	0	2	0	1	3	2	4	2
EDU	Education services supply	5	5	1	3	0	0	3	5	0	3

0 (no relevance)
1 (very little impact by the hazard)
2 (critical infrastructure functions could be somewhat affected by this risk)
3 (critical infrastructure functions could be affected by this risk)
4 (critical infrastructure function could be significantly affected by this risk)
5 (critical infrastructure functions could be severely affected)

The rest of this chapter reviews the various infrastructure systems, analyzing both the risks and the institutional and regulatory framework specific to each system in order to identify targeted measures to enhance resilience.

A. TRANSPORT

The entire sector suffers from dilapidated and/or inadequate infrastructure, making it particularly vulnerable to the risk of disasters. Any disruption to transport services can easily result in the isolation of several localities, due in particular to the Grande Ile's vast surface area, its topography and the predominance of the rural population, which is also geographically highly dispersed. The island's remoteness from the main international markets makes the resilience of its transport infrastructure even more important.

The sector is made up of four sub-sectors: air, sea, road and rail.

RECOMMENDATIONS FOR THE TRANSPORT SECTOR

The following practical recommendations emerge from the analysis.

Table 6: Recommendations for the entire transport sector

RECOMMANDATIONS	FOCUS AREAS	PRINCIPLES	ENTITIES INVOLVED	POTENTIAL PARTNERS	PRIORITY	TIMELINE
Strengthen the independence and sovereignty of regulatory authorities in the transport sector to ensure transparency of construction operations (from procurement to monitoring of completed work).	4. Governance and coordination		ATT, ACM, APMF, DGSR (Lead)		High	Short-term
Integrate infrastructure resilience into transport sub-sector codes (air, rail and maritime), as this is not sufficiently explicit in framework documents.	5. Policies, Standards and Regulations		MTM	CDRI, UNDRR	High	Short-term

1. Air Transport

Madagascar has around 80 airports and airfields of varying size, spread throughout the country. The primary international gateway is Ivato airport, located close to the capital city and home to the national airline. In addition to this major airport, the country has 22 medium-sized airports or airfields, as shown on Map 1. The remaining 60 airports are smaller, with runways made of grass and gravel in most cases.

Being an island, Madagascar relies heavily on air transport for international connectivity and access to world markets. Airports are essential hubs for key economic activities, including tourism and international trade of goods.

Airports and airfields also play a vital role in terms of domestic connectivity, linking remote regions to major cities and urban centers, as the country is vast and road transport is difficult over long distances and in certain regions, particularly during the rainy season. In times of crisis, airports are also used to convey emergency supplies, humanitarian aid and medical assistance to affected areas.

STAKEHOLDERS AND REGULATORY FRAMEWORK

POLITICAL DECISION-MAKERS	**The Ministry of Transport and Meteorology / General Directorate for Air Transport** is responsible for developing, implementing, monitoring, and ensuring coordination of the State's general policy for transport and meteorology. It pursues the strategic objectives set out in the Initiative Emergence Madagascar (IEM). Its mission is to guarantee efficient transport services and reliable weather monitoring to support the country's development.
REGULATORS	**Aviation Civile de Madagascar** guarantees air transport safety in Madagascar through legislation, strict supervision, and in-service training of its technical staff. It delivers and controls the required authorizations and certificates, while supervising activities to identify and address security issues. Additionally, it encourages competition in the air transport sector and administers the country's air agreements in compliance with its international obligations.

OPERATORS	**Ravinala Airports** has been selected by the Government to operate, maintain, develop and finance two airports: Antananarivo (Ivato) and Nosy Be (Fascene) for a 28-year period (objectives: to improve capacity, safety and environmental standards). Ravinala Airport is a consortium comprising Meridiam, ADP International, Bouygues Bâtiment International and Colas. **Aéroports de Madagascar (ADEMA)** operates the country's secondary airports and airfields, which are less profitable due to limited traffic. ADEMA receives part of the concession fees paid by Ravinala to the Government to cover its costs.[12]

Figure 6. Overview of the Institutional and Policy Framework related to Infrastructure Resilience in the Transport Sector

AIR TRANSPORT

POLITICAL ACTORS

Director General of Air Transport, Ministry of Transport and Meteorology.

REGULATORS

Civil Aviation Authority of Madagascar

OPERATORS

Ravinala Airports | ADEMA

POLITICAL & REGULATORY FRAMEWORK

- LOI N°96-033 sur la **libération du transport aérien à Madagascar.**
- LOI N°99-031 relative à **l'Aviation Civile de la République de Madagascar**. | **Titre VI: Réglementation économique de l'infrastructre aéronautique.**
- Note N°057 - DREGGuide de rédaction d'un manuel relatif à l'entretien des aéronefs.
- GUI-ACM/DSE/AGA-20: Guide d'établissement d'un plan d'urgence d'aérodrome.

Source: Authors

DISASTER RISKS

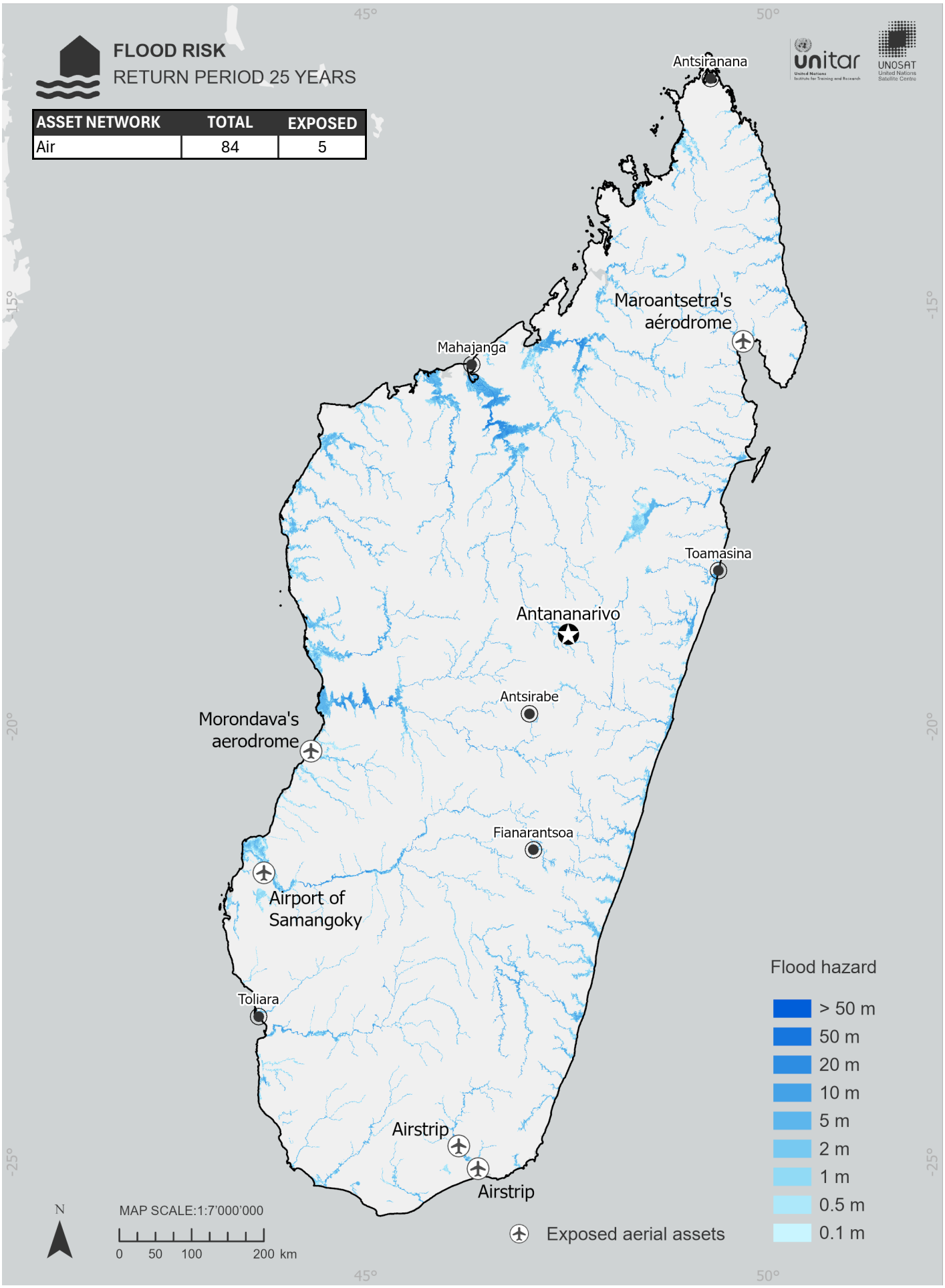
Airports are exposed to a range of hazards that can compromise their operations and prevent them from fulfilling their role as transport hubs and economic drivers. Airports' exposure to these hazards often depends on their location (e.g., flood-prone areas), while their vulnerability to these hazards is affected by local conditions (e.g., physical features) and the measures taken to enhance airports' disaster resilience. In addition to physical infrastructure, the sector's resilience also depends on the availability of flying equipment, which can be a challenge in Madagascar (e.g. number of aircraft, outmodedness). Finally, ageing infrastructure and structural failures resulting from inadequate maintenance can lead to runway closures and service interruptions involving protracted repairs.

12. https ://actu.orange.mg/ladema-commence-a-se-redresser-apres-des-difficultes-financieres/

The combination of geographical data from hazard models with infrastructure geolocation allows to locate a number of vulnerabilities. Map 1 shows a flood risk model with a 25-year return period, accessible via CDRI's GIRI platform, as well as air transport assets. Analysis of the data reveals that five assets are at risk of experiencing flood depths between 1.5 to 3.5 meters. Flooding resulting from heavy rains or storms can submerge runways and terminals, disrupting operations. As an illustration, in 2015, heavy torrential rains flooded the former Ivato international airport, rendering runways temporarily unusable and causing flight delays.[13]

13. Aéroport d'Ivato : Sept vols perturbés par l'inondation à l'aérogare - (midi-madagasikara.mg) https://midi-madagasikara.mg/aeroport-divato-sept-vols-perturbes-par-linondation-a-laerogare/

Map N°1. Risks of Flooding in the Air Transport Sector



Airport infrastructure and operations are also vulnerable to other hazards:

- Cyclones, with their destructive winds and heavy rains, have the potential to cause extensive damage to airport facilities
- Cyber-attacks on airport systems as well as system failures represent a security risk likely to lead to operational disruptions
- Fire hazards, especially during drought conditions, can quickly escalate, endangering facilities or impairing visibility, thus affecting safe flight operations
- Pandemics, as seen with Covid-19, result in travel restrictions and quarantine measures, severely disrupting airport operations. The Covid-19 pandemic has significantly impacted air transport in Madagascar, causing Air Madagascar to lose 90% of its revenues in 2020 and severely affecting the tourism sector.[14] The closure of borders has exacerbated the situation, entailing heavy job losses.

While other risks like rising sea levels, heatwaves, droughts, landslides, and earthquakes may not represent immediate threats, they necessitate ongoing monitoring due to their potential to compromise critical infrastructure.

RESILIENCE MEASURES

A few "policy" measures have already been taken to bolster airport resilience against disaster risks, including the Aircraft Maintenance Manual (Note No. 057-DREGG) and the Aerodrome Emergency Planning Guide (GUI-ACM/DSE/AGA-20). Adherence to Principle 2.7's rigorous maintenance schedule is crucial to achieving the resilience of aeronautical infrastructure. Regular maintenance operations are essential to ensure aircraft safety and reliability, prevent unplanned outages, minimize service disruptions, and optimize long-term costs, thereby improving performance and sustainability. Concurrently, and in accordance with Principle 2.4, the Aerodrome Emergency Planning Guide plays a pivotal role in the effective integration of emergency management. It delineates clear procedures, assigns responsibilities and coordinates actions to allow the provision of a quick and well managed response. Such structured emergency planning reduces confusion, improves preparedness through training and exercises, and contributes to maintaining airfield safety and resilience.

Other structural measures have been taken or are planned. The construction of the new Ivato international airport, managed by Ravinala Airports, is the cornerstone of the efforts to enhance the resilience of the aviation sector. Concurrently, ADEMA is spearheading the modernization and rehabilitation of various airports to ensure their suitability and resilience, thereby supporting the expansion of air links. Rehabilitation projects are aimed particularly at supporting resilient airport infrastructure, including Toliara airport, which has significant development potential.

14. A Madagascar, le secteur du tourisme est laminé par la crise sanitaire (lemonde.fr) https://www.lemonde.fr/afrique/article/2021/07/13/a-madagascar-le-secteur-du-tourisme-est-lamine-par-la-crise-sanitaire_6088177_3212.html

RECOMMENDATIONS FOR THE AIR TRANSPORT SECTOR

The following practical recommendations emerge from the analysis.

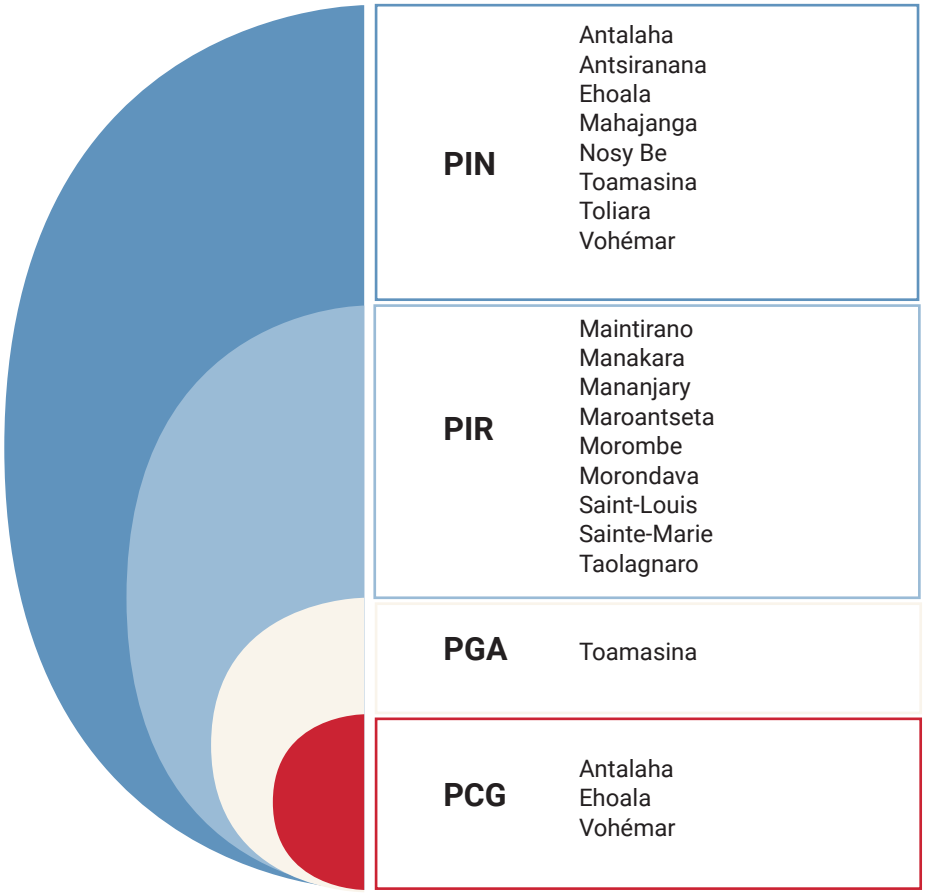
Table 7. Recommendations for the Air Transport Sector

RECOMMENDATIONS	FOCUS AREAS	PRINCIPLES	ENTITIES INVOLVED	POTENTIAL PARTNERS	PRIORITY	TIMELINE
Require stress tests to be performed, and make sure that such tests consider a wide range of failure or shutdown scenarios (including the risk of a pandemic).	1. Data, Monitoring and Evaluation	P1.4.	Ministry of Transport and Meteorology (Lead), Ravinala Airports, Gendarmerie	Transit agencies, National and foreign airline companies	High	Short-term
Reinforce preventive maintenance programs for equipment and structures to guarantee their proper functioning at all times. This will be achieved by integrating advanced technologies and proactive strategies, and by prioritizing maintenance tasks based on the criticality of infrastructure for the operation of the sector.	5. Policies, Standards and Regulations	P2.7	Ministry of Transport and Meteorology (Lead), Ravinala Airports, Gendarmerie	National and foreign airline companies	High	Short-term
Integrate resilience to hazards, protection of critical airport infrastructure and guarantees of continuity of airport operations into the National Aviation Action Plan (NAAP).	5. Policies, Standards and Regulations	P5.1	Ministry of Transport and Meteorology	CDRI, UNDRR	High	Medium-Term
Encourage the revision of the air transport sector's development policy, with a view to facilitating the entry of diverse companies, which can lead to optimized service offerings and fare structures, and mitigate the risks of service interruptions or stoppages.	5. Policies, Standards and Regulations	P6.4	Ministry of Transport and Meteorology (Lead), Ministry of Foreign Affaires	Foreign airline companies	Moderate	Medium-Term

2. Maritime Transport

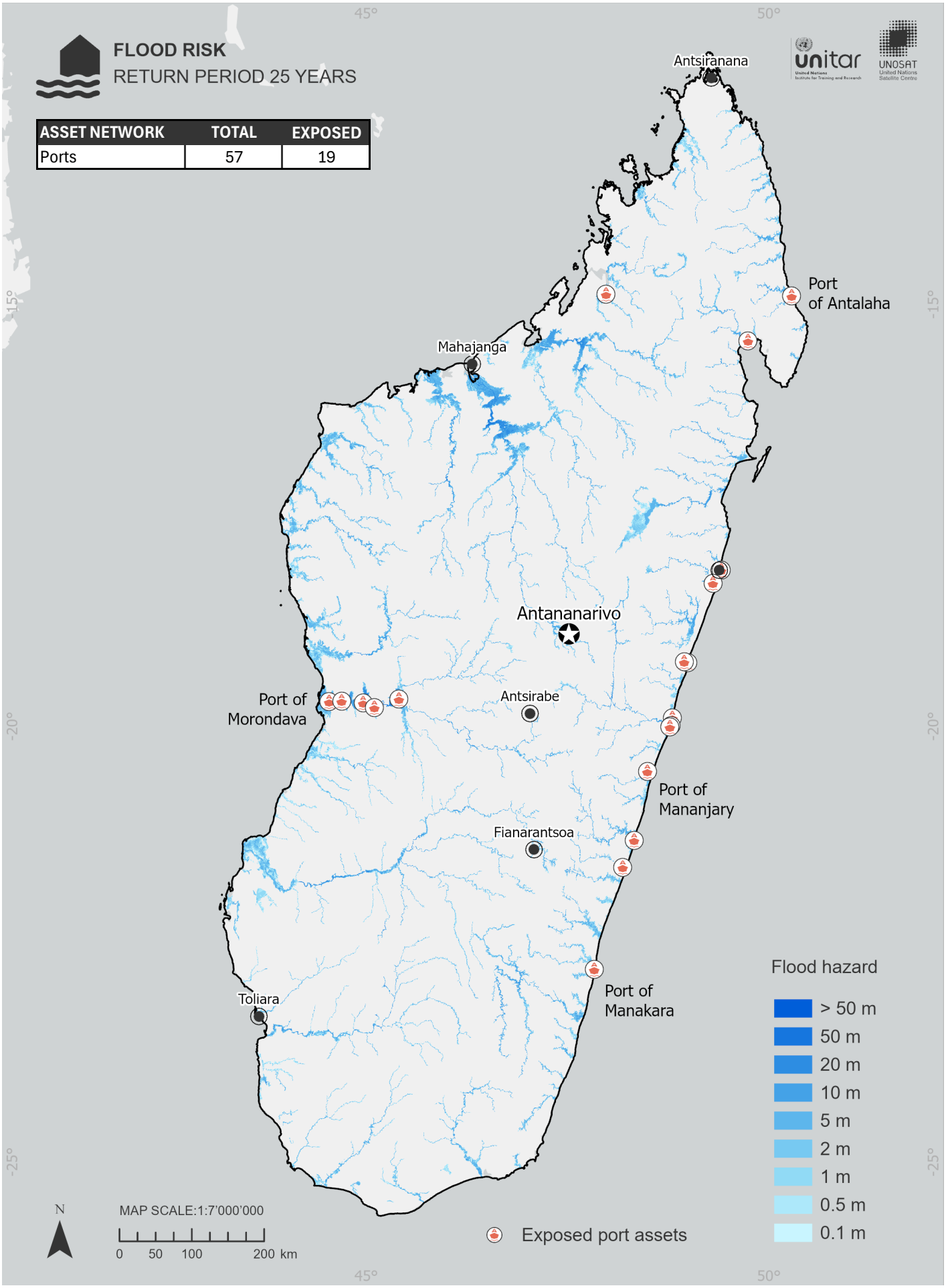
Maritime transport plays a crucial role in supporting Madagascar's economy. The resilience of this sector is therefore of paramount importance to the country. International trade depends almost entirely on maritime transport, as noted, for instance, in vanilla, agricultural products, minerals and seafood exports. Maritime transport infrastructure also ensures cohesive connectivity across the island.

The country's ports have diverse capacity and strategic significance. Madagascar has seventeen (17) ports classified as ports of national interest (Ports d'Intérêt National, PIN) and ports of regional interest (Ports d'Intérêt Régional, PIR).[15]



15. *https ://www.apmf.mg/les-sous-secteur/portuaire / PIN: Port of national interest ; PIR: Port of regional interest; PGA: Autonomous port; PCG: Ports with global concession*

Map N°2. Vulnerability of Maritime Ports to Flooding Risks



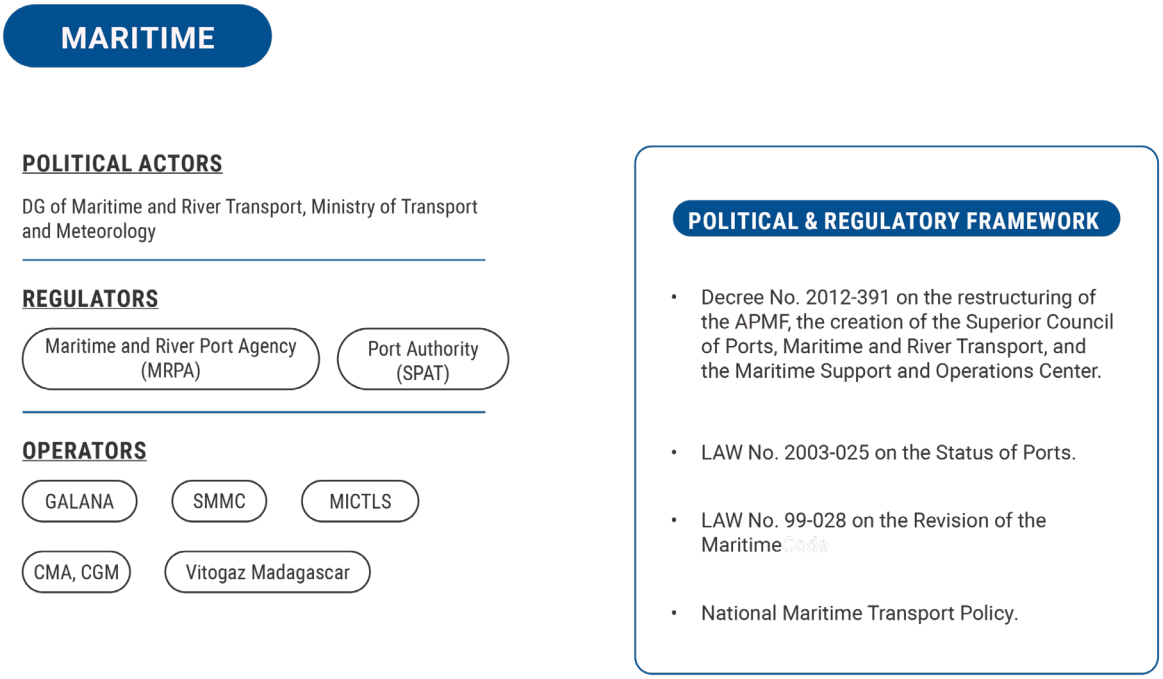
Map 2 presents a flood risk model with a return period of 25 years—accessible via CDRI's GIRI platform—, as well as port assets. Data analysis show that approximately 19 of 57 ports are facing potential flooding risks, including the country's major port of **Toamasina**, the primary gateway for approximately 75% of the nation's international freight.

STAKEHOLDERS AND REGULATORY FRAMEWORK

Understanding the institutional and regulatory framework is central in identifying the measures to enhance the sector resilience.

POLITICAL DECISION-MAKERS	• **Ministry of Transport and Meteorology**
REGULATORS	• The **Agence Portuaire Maritime et Fluviale (APMF)** is the authority responsible for regulating Madagascar's maritime and river port sector. It plays a pivotal role in implementing national policies. It administers maritime and river port affairs, while ensuring the safety and security of activities within these waterways. As a licensing body, it supervises autonomous ports and regulates the use of public port and maritime domains. Furthermore, APMF engages in coastline protection and marine environment conservation, while fostering the development and promotion of this key sub-sector. • **Port authorities** such as the Société du Port à Gestion Autonome de Toamasina (SPAT), which is responsible for port expansion works.
OPERATORS	• **Galana,** part of Group Rubis, operates the Toamasina Oil Terminal Platform. Its refinery is the country's main fuel storage terminal. • **MICTSL**, a 100% subsidiary of the Philippine ICTSI group, is a private company that has been managing the Toamasina container terminal since 2005 under a concession granted by the Government. • The State-owned **SMMC** manages general cargo at Toamasina. • **Groupe CMA CGM** (leader in container transport) offers services to and from Madagascar's seven ports. • **VITOGAZ Madagascar,** part of Groupe Rubis Group, operates a gas terminal in Mahajanga.

Figure 7. Overview of the Institutional and Policy Framework related to Infrastructure Resilience in the Maritime Transport Sector



Source : Authors

DISASTER RISKS

Ports in Madagascar are vulnerable to a range of risks that can disrupt operations and threaten their critical role in trade and the economy. Their vulnerability to such risks is heavily influenced by geographic location, especially for those situated in areas prone to cyclones, floods, and high tides. Map 2 illustrates the exposure of Madagascar's ports to flood risks over a 25-year return period.

The stress test analysis highlighted specific hazards of high relevance to Madagascar's ports and waterways.

- Floods and cyclones can severely damage quays, warehouses, and critical equipment, disrupting port operations and impacting the supply chain. Cyclone Enawo has demonstrated this vulnerability by rendering the port of Antalaha temporarily inaccessible for a week.
- Rising sea levels exacerbates flooding risks in ports and waterways, further complicating port operations.
- While heat waves and droughts have a limited direct impact on port infrastructure, fires have the potential to cause extensive damage, threatening cargo safety and management.
- Earthquakes, though rare, pose risks to ground-based infrastructure.
- Pandemics such as Covid-19 can significantly disrupt regional and global supply chains, affecting maritime trade.
- Cybersecurity breaches, although infrequent at national level, can impair international waterway communications.
- Finally, corruption and structural failures resulting from substandard construction of ports and the dilapidated state of port infrastructure—the majority of which were built during the colonial era—increase the risk of accidents.

RESILIENCE MEASURES

As part of its commitment to developing and enhancing the resilience of its maritime sub-sector, Madagascar has adopted a new plan, namely the draft National Maritime Transport Policy (PNTM), developed in collaboration with the International Maritime Organization (IMO). The PNTM is centered around five key pillars: transparent, honest, professional, and inclusive governance in maritime transport; competent human resources at the service of the maritime transport sector; modern ports that are safe, competitive, and locally focused; safe and secure ships and shipments; and a clean environment that is protected from the harmful effects of maritime transport activities.

A number of ports are currently undergoing structural enhancements. The port of Toamasina is benefiting from a major US$640 million expansion project co-financed by JICA. The project, which is anticipated to be completed by 2026, includes the reinforcement and extension of the existing breakwater to bolster its resilience against cyclonic waves. It also aims to increase the port's capacity and depth to accommodate larger vessels. Additionally, feasibility studies on the rehabilitation of the port of Manakara have been conducted via a public-private partnership, supported by the African Development Bank (AfDB). The Government of Madagascar is also considering the development of

the ports of Antsiranana in the north and Taolagnaro in the south, by improving the road networks that provide access to these facilities.

Regulatory and institutional improvements are still needed. Recent projections of climate change call for particular attention from coastal infrastructure stakeholders. It is vital to integrate climate change considerations in the planning and management of coastal infrastructure, by adopting comprehensive strategies aimed at risk mitigation. Public authorities must spearhead the development of regulations that promote adaptation. Active involvement from financial institutions and the insurance sector is equally important. Adaptation strategies must be customized to address specific risks, whether they are episodic or slow-onset, balancing the need for short-term protective measures with long-term resilience strategies. Moreover, effective coordination is critical for the successful implementation of national adaptation plans and coastal area management policies.

RECOMMENDATIONS FOR THE MARITIME TRANSPORT SECTOR

Table 8. Recommendations for the Maritime Transport Sector

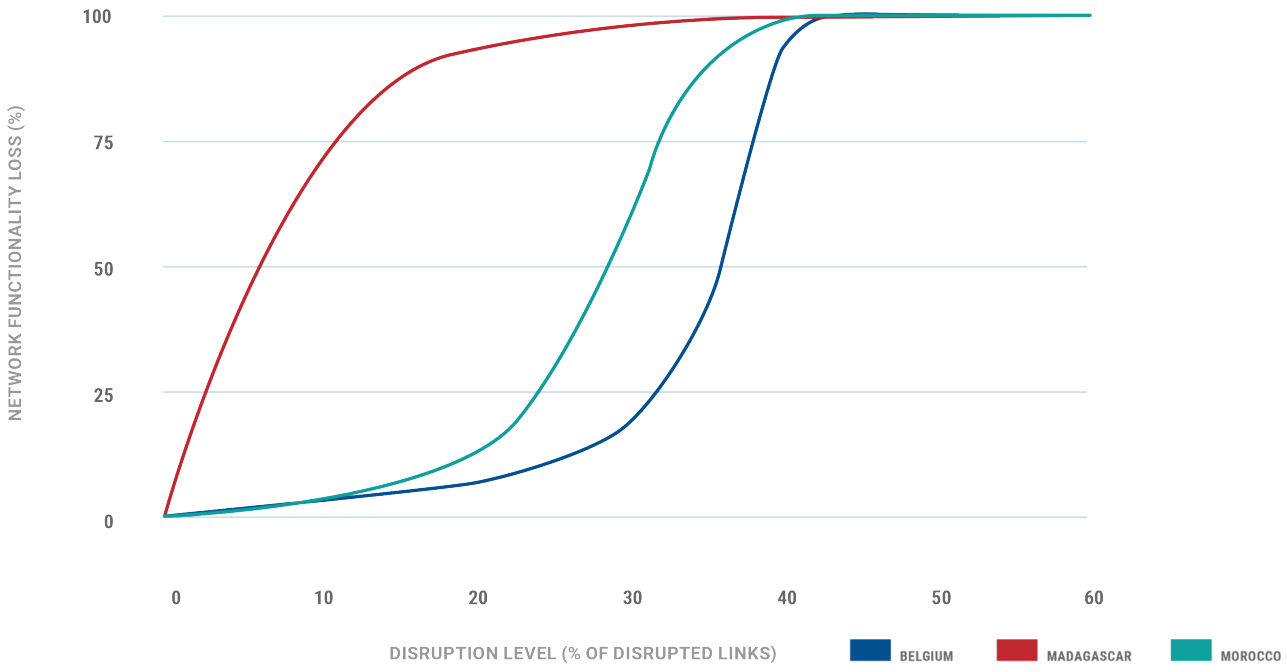
RECOMMANDATIONS	AXES	PRINCIPES	AGENCE RESPONSABLES	PARTENAIRES POTENTIELS	PRIORITÉ	DÉLAI
Encourage the publication of the National Maritime Transport Policy (PNTM).	5. Policies, Standards and Regulations	P1.1	Ministry of Transport and Meteorology (Lead), CPGU	Development Banks, UNDP	High	Short-term
Implement the national master plan for port development in Madagascar and improve this plan by integrating the principles of resilient infrastructure.	5. Policies, Standards and Regulations	P1.2	Ministry of Transport and Meteorology, (Lead), Agence portuaire maritime et fluvial	Development Banks, UNDRR	Moderate	Medium-Term
Conduct a comprehensive inventory of port infrastructure systems, along with vulnerability mapping.	1.Data, Monitoring and Evaluation	P1.3	Ministry of Transport and Meteorology, Agence portuaire maritime et fluvial, CPGU, MDPT, BNGRC (Lead)	CDRI, UNDRR UNOSAT, World Bank	High	Medium-Term
Develop an investment plan as well as public-private partnerships to strengthen the resilience of port infrastructure in Madagascar.	3.Infrastructure Project (Structural Measures)	P3.1	Ministry of Transport and Meteorology, Agence portuaire maritime et fluvial, MEF (Lead)	World Bank, AFDB, JICA	Moderate	Medium-Term

3. Road Transport

Madagascar's road network is generally in poor condition, which makes it particularly vulnerable to disaster risks. Only 13% of roads are paved. While national roads (routes nationales, RN), particularly primary national roads (routes nationales primaires, RNP) on the structuring network maintain a fair condition (52%), the broader network is in poor condition (World Bank, 2023) . Furthermore, road segments (including some RN) have disappeared, exacerbating the destitution of affected regions and populations, particularly in the South, which is the poorest part of the country.

The country's low-density road network is highly vulnerable to dysfunction from even minor damage. In contrast to more resilient road systems like those in Belgium or Morocco, which can withstand the loss of multiple road sections without significant impact on overall connectivity, Madagascar relies on single roads to connect large parts of the territory (see Figure 9).

Figure 8. The transport systems in Belgium and Morocco are designed to withstand significant road disruptions than that of Madagascar



Source: Rozenberg, J., C. Fox, M. Tariverdi, E. Koks, and S. Hallegatte. 2019, "Road Show: Comparing Road Network Resilience around the World." Background paper, World Bank, Washington, DC.

16. https ://documents1.worldbank.org/curated/fr/130911468086644653/047856072_201407225004131/additional/883230REPLACEM00Box385221B00PUBLIC0.pdf

STAKEHOLDERS AND REGULATORY FRAMEWORK

POLITICAL DECISION-MAKERS	• **Ministry of Transport and Meteorology** / General Directorate for Land Transport is responsible for developing, implementing, monitoring and coordinating the State's general policy for transport and meteorology. It pursues the strategic objectives set out in the Initiative Emergence Madagascar (IEM). Its mission is to guarantee efficient transport services and reliable weather monitoring to support the country's development. • **Ministry of Public Works**
REGULATORS	• **The Agence routière de Madagascar (ARM)** oversees the national road network and acts as the delegated contracting authority for implementing programs set forth by the Ministry of Public Works. It aligns its activities with government priorities while also considering the availability of funds from the Road Fund and external donors. Additionally, ARM is also responsible for monitoring and ensuring effective technical, administrative, and financial management of projects
OPERATORS	• **The Fonds Routier de Madagascar (FRM)** is responsible for collecting resources and financing for roadworks, as well as validating agreements between project owners and contractors. It ensures the accuracy and completeness of payment vouchers before they are submitted to the Treasury for processing. Furthermore, by conducting field audits, the FRM inspects the executed works to identify areas for improvement and provide recommendations to project owners.
USERS	• **Transport companies** • **Motorized and non-motorized users** • **Passengers**

Figure 9. Overview of Stakeholders and Political and Regulatory Frameworks in the Road Transport Sector

ROAD TRANSPORTATION

POLITICAL ACTORS

Directorate General of Land Transport, Ministry of Transport & Meteorology

Ministry of Public Works

REGULATORS

Road Agency of Madagascar (RAM)

OPERATORS

Road Fund of Madagascar (RFM)

POLITICAL & REGULATORY FRAMEWORK

- National Transport Policy and Strategy (ongoing).
- Decree No. 2020-1156 of September 16, 2020, establishing the National Standard for Flood-Resistant Road Infrastructure and Geological Phenomena in Madagascar **(NIRIPG).**
- LAW No. 2004-053 establishing the principles of land transport policy.

Source: Authors

DISASTER RISKS

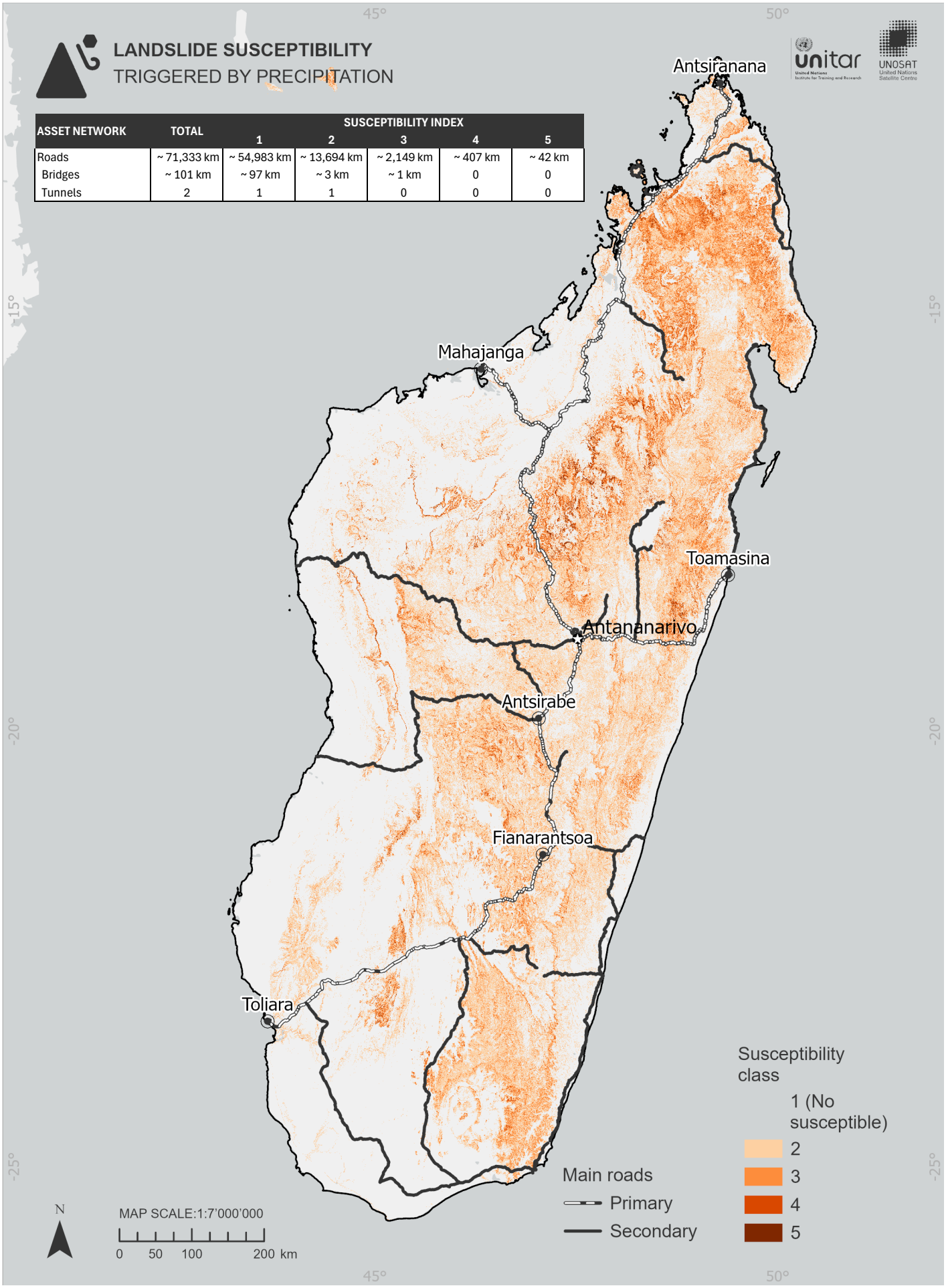
Roads are vulnerable to a wide range of risks and hazards that can compromise their functionality and economic importance. Extreme weather events like cyclones, floods, and landslides represent significant threats, especially in regions prone to these phenomena. These events can damage road infrastructure, blocking lanes and disrupting the flow of passengers and cargo transport. Beyond natural disasters, roads may be affected by other factors such as major accidents, structural failures from poor maintenance, and intentional vandalism.

An in-depth analysis can be conducted using geolocated data:

- Map 3, available on CDRI's GIRI platform, illustrates a landslide vulnerability model alongside road transport infrastructure in Madagascar. Data analysis indicates that approximately 16,292 km of roads, 4 km of bridges, and 1 tunnel are at potential risk of landslides.
- Map 4 showcases a flood risk vulnerability model with a 25-year return period, available on CDRI's GIRI platform, alongside road transport assets. Data analysis by UNOSAT indicates that around 3,404 km of roads and 33 km of bridges are potentially exposed to flood depths from 0.1 to 3 meters.

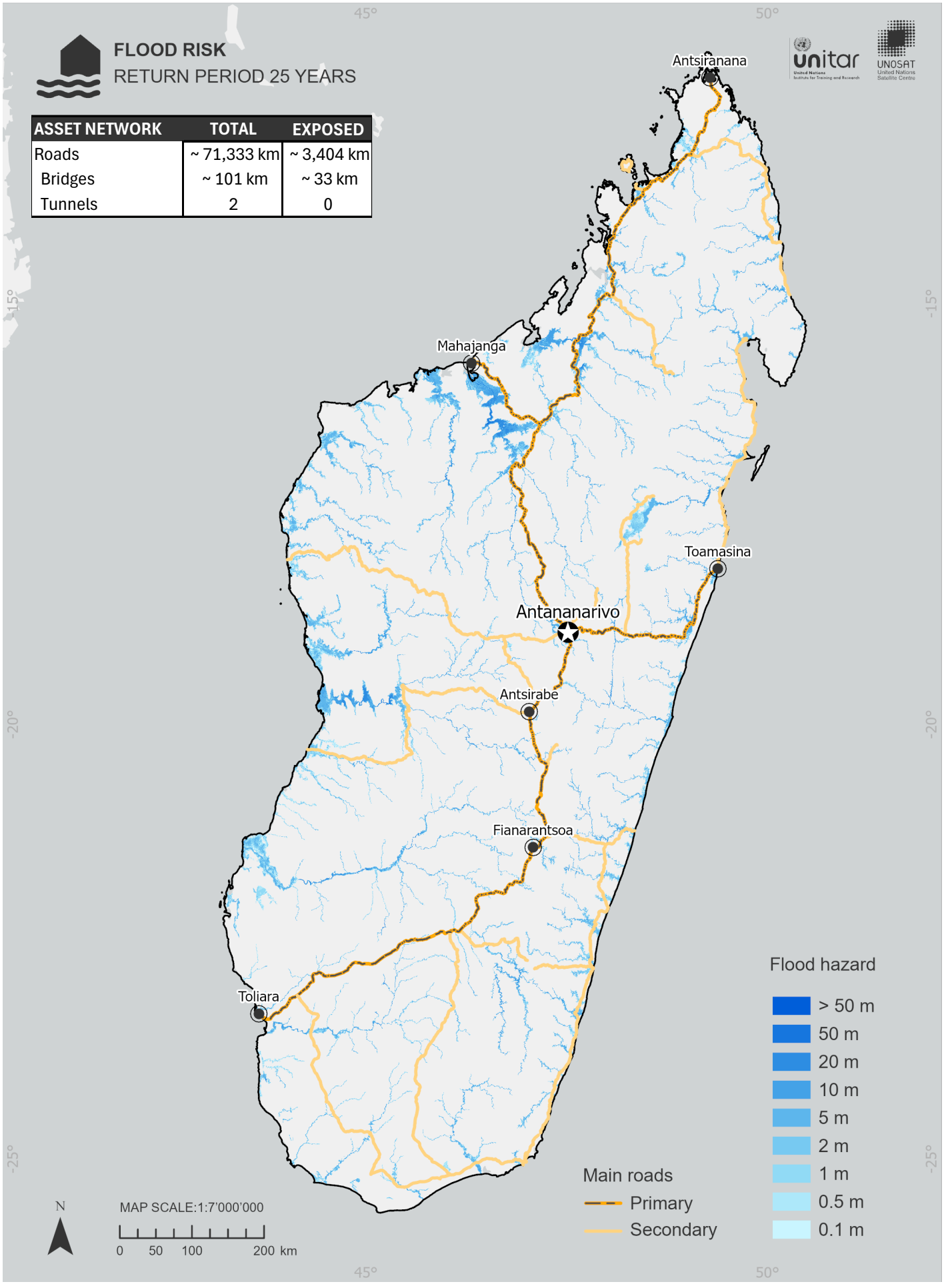
This analysis equips authorities with valuable insights to implement targeted resilience-building measures in the most vulnerable areas.

Map N°3. Vulnerability of Road Infrastructure to Landslides



ASSET NETWORK	TOTAL	SUSCEPTIBILITY INDEX				
		1	2	3	4	5
Roads	~ 71,333 km	~ 54,983 km	~ 13,694 km	~ 2,149 km	~ 407 km	~ 42 km
Bridges	~ 101 km	~ 97 km	~ 3 km	~ 1 km	0	0
Tunnels	2	1	1	0	0	0

Map N°4. Vulnerability of Road Infrastructure to Flooding



RESILIENCE MEASURES

The Government has introduced the national standards applicable to road infrastructure resistant to floods and geological phenomena (Normes Nationales pour les Infrastructures Routières Résistantes aux Inondations et aux Phénomènes Géologiques, NIRIPG) to counter major threats likely to damage road infrastructure. These standards aim to enhance the resilience and protection of road infrastructure against climatic and geological hazards, thus ensuring their sustainability. They set out technical requirements for implementation at every stage of the design, construction, maintenance and monitoring of road infrastructure, alongside environmental recommendations.

The national climate change strategy for the transport sector (Stratégie Nationale relative au Changement Climatique pour le secteur Transport) is another resilience measure put in place by the Government. Its overall aim is to reduce greenhouse gas emissions from the transport sector, and to step up the implementation of mitigation measures.

With regard to resilient road infrastructure projects, an allocation of US$100 million was expected in 2023 from the World Bank via the Crisis Response Window of the Road Sector Sustainability Project (RSSP), followed by additional funding to replenish resources. This initiative aims to swiftly respond to the Government's request to rehabilitate road, bridge, power, and rail infrastructure following the four cyclones that hit Madagascar.

Additionally, the European Investment Bank supported the Agence routière de Madagascar in its modernization projects, co-financed by the European Union. These projects aim to enhance transport links across the island by constructing and renovating climate-resilient roads, specifically focusing on the RN6 road in the north, stretching 234 km from the port of Antsiranana to Ambanja, and the RN13 road in the south, covering 114 km from the port of Taolagnaro to Ambovombe.

RECOMMENDATIONS FOR THE ROAD TRANSPORT SECTOR

Table 9. Recommendations for the Road Transport Sector

RECOMMENDATIONS	FOCUS AREAS	PRINCIPLES	ENTITIES INVOLVED	POTENTIAL PARTNERS	PRIORITY	TIMELINE
Establish and supply essential equipment to the interministerial and intersectoral unit for monitoring the application of the NIRIPG standards.	4. Governance and Coordination	P1.2	Ministry of Public Works	World Bank, AFDB, European Union, UNOPS	High	Short-term
Adopt innovative road construction techniques like the honeycomb structure to enhance road resilience.	3. Infrastructure projects (Structural Measures)	P2.8	Ministry of Public Works	World Bank, AFD, European Union, UNOPS	High	Medium-term
Disseminate standards through widespread awareness-raising campaigns, including using posters in local offices and leveraging mass media spots.	2. Capacity building	P5.2	Ministry of Public Works	Mass media, World Bank, European Union	High	Medium-term
Strengthen inter-ministerial coordination through intensified consultation and data sharing within existing directorates of the ministry to enhance planning and implementation of resilient road infrastructure projects.	4. Governance and Coordination	P3.3	Ministry of Public Works, CPGU (Lead), BNGRC, PNRRC.		High	Medium-term
Encourage community engagement strategies related to road maintenance, particularly through the High Intensity Labor (HIMO) approach, and raising awareness of local populations about the risks associated with road wear and tear or degradation of roads stemming from everyday activities.	3. Infrastructure projects (Structural Measures)	P4.4	Ministry of Public Works, CTD, DGSR (Lead), DRMEDD	World Bank, AFDB, European Union	High	Medium-term
Reinforce the application of the continuity plan for the provision of critical services during disasters.	4. Governance and Coordination	P2.5	Ministry of Public Works, CPGU, DRTP		High	Medium-term
Involve private initiatives in road infrastructure construction, maintenance and investment operations, especially in rural areas, by signing cooperation agreements with private entities.	3. Infrastructure Projects (Structural Measures)	P5.2 et P5.3	Ministry of Public Works, MEF	Private sector platforms	High	Medium-term
Reactivate the road funds and accelerate availability of maintenance funds for road construction projects.	4. Governance and Coordination	P2.8	Ministry of Public Works, Agence Routière	World Bank, AFDB, European Union, AFD	Moderate	Long-term

4. Rail Transport

Rail transport plays a vital role as an alternative to road transport, particularly along the main corridor between the capital city and Toamasina, the country's main port. The 732 km "North" network (Tananarive–Côte Est (TCE) line) effectively alleviates the pressure on roadways by minimizing damage from heavy goods vehicles, especially for the transport of heavy and/or dangerous materials, such as cement, hydrocarbons, chromite, containers and rice. The advantages of rail are clear, with costs per ton-km up to 40% lower than road transport and improved fuel efficiency. The concessioning of the network to Madarail in July 2003 has allowed for significant investments in infrastructure and rolling stock (container carriers, tank wagons, more powerful locomotives) leading to a marked increase in rail's market share compared with road.

Financial challenges are nevertheless threatening the resilience of the rail network by hindering necessary maintenance and new investments. The resilience of the 163 km "South" network (Fianarantsoa–Côte Est (FCE) line) is particularly jeopardized by ongoing financial difficulties. Despite receiving regular subsidies from the Ministry of Transport[17], these funds are only sufficient to cover direct operating costs, leaving pressing needs for significant investment in both infrastructure and rolling stock, particularly locomotives, as only one has been operational since 2009. Given the "South" line's social function to connect a region inhabited by approximately 100,000 people, who have no alternative access, it primarily generates revenue from passenger services, which outstrips freight revenue.[18]

STAKEHOLDERS AND REGULATORY FRAMEWORK

POLITICAL DECISION-MAKERS	• **The Ministry of Transport and Meteorology** is responsible for developing, implementing, monitoring and coordinating the State's general policy on transport and meteorology. It pursues the strategic objectives set out in the Initiative Emergence Madagascar (IEM). Its mission is to guarantee efficient transport services and reliable weather monitoring to support the country's development.
OPERATORS	• **MADARAIL,** or Madagascar Railways, is a crucial player in freight transportation across Madagascar's Northeast Network. Beyond transportation services, Madarail conducts the maintenance and renewal of tracks, as well as the development of rail infrastructure

17. World Bank, 2023 / https://documents1.worldbank.org/curated/fr/130911468086644653/047856072_201407225004131/additional/883230REPLACEM00Box385221B00PUBLIC0.pdf
18. World Bank, 2023 / https://documents1.worldbank.org/curated/fr/130911468086644653/047856072_201407225004131/additional/883230REPLACEM00Box385221B00PUBLIC0.pdf

USAGERS	• Companies relying on rail transport. • Passengers

Figure 10. Overview of the Institutional and Policy Framework related to Infrastructure Resilience in the Rail Transport Sector

RAIL TRANSPORT

POLITICAL ACTORS

Ministère du transport et de la Météorologie.

OPERATORS

MADARAIL

POLITICAL & REGULATORY FRAMEWORK

- **Arrêté N°831/2010,** portant maintien de la ligne FCE reliant Fianarantsoa et Manakaraet création d'un Comité de Gestion.
- **Décret N°2005-867**: Fixant les attributions de gestions du compte de commerce intitulé *"Fonds d'Investisement et de Développement Ferroviaire."*
- **Décret N°2003-410, du 27 Mars 2003:** portant approbation de la Convention de concession de gestion et d'exploitation du réseau ferroviaire nord de la République de Madagascar.

Source: Authors

The existing regulatory frameworks governing rail transport and infrastructure in Madagascar are outdated and insufficient to address today's needs. Policy frameworks for rail transport are generally governed by the national transport policy. Discussions are still ongoing, however, for this specific sub-sector. Key resilience criteria are not taken into account to cope with present challenges, such as climate change and other hazards. This gap compromises the sustainability and efficiency of rail infrastructure, hindering their capacity to respond to contingency and maintain essential services during disruptions. Therefore, it is imperative to swiftly update the sector's regulatory and policy frameworks to incorporate resilience principles in order to foster the development of strong and flexible infrastructure.

DISASTER RISKS

Rail transport in Madagascar regularly faces major challenges related to climate-related uncertainties. Rail transport is crucial for the movement of goods between regions, especially heavy items and construction materials. However, heavy rains and frequent cyclones can lead to landslides and flooding, which not only damage rail infrastructure but also disrupt continuity of service. This vulnerability underscores the need for ongoing maintenance and reinforcement of railroads to enhance their resilience and ensure they can withstand extreme weather events.

RECOMMENDATIONS FOR THE RAIL TRANSPORT SECTOR

The following practical recommendations emerge from the analysis.

Table 10: Recommendations for the Rail Transport Sector

RECOMMENDATIONS	FOCUS AREAS	PRINCIPLES	ENTITIES INVOLVED	POTENTIAL PARTNERS	PRIORITY	TIMELINE
Implement rail infrastructure resilience standards alongside the National Rail Transport Action Plan, incorporating specific measures for tackling climate change and enhancing infrastructure resilience.	5. Policies, Standards and Regulations	P5.1	Ministry of Transport		High	Short-term
Conduct a comprehensive inventory of operational railway infrastructure systems, along with detailed mapping, to assess their vulnerability and resilience to environmental risks and climatic hazards, allowing for the prioritization of strengthening measures and adaptation actions.	1.Data, Monitoring and Evaluation	P5.6	Ministry of Transport, CPGU,	UNOSAT, UNITAR, UNDRR	Moderate	Medium-term
Increase investment and foster public-private partnerships in rail transport to facilitate movements of people and transport of goods, by integrating resilient infrastructures that can withstand disasters and the effects of climate change, thus guaranteeing the continuity of services even during major disruptions.	3.Infrastructure Projects (Structural Measures)	P6.2	Ministry of Transport	World Bank, European Union	High	Long-term

B. ENERGY

The energy sector is characterized by precarious resilience due in particular to poor geographical coverage. Overall, only 22% of the population is connected. This challenge is particularly acute in rural areas with a mere 5% of inhabitants having access to electricity. Despite a relatively better coverage in urban areas, energy access remains insufficient with only 14% of urban households being connected to the main grid and 22% relying on mini-grids or off-grid solar technologies.[19] The country's goal is to increase overall access to 70% by 2030.

Those connected to the electricity grid face frequent power cuts and voltage fluctuations, leading to an estimated 14% loss of sales[20], which disrupts daily life and hinders economic development. The main energy operator struggles to fully utilize its capacity due to insufficient maintenance of power plants. These challenges not only affect the quality of life of the population but also serve as significant barriers to private sector growth and the country's overall development.

Power generation heavily relies on both fossil fuels and water resources. Electricity production in Madagascar is mainly based on fossil fuels, with oil and coal accounting respectively for 49% and 19% of total production. Continuity of service therefore depends on uninterrupted access to these resources. Renewable energies contribute 33% to electricity production, primarily from hydroelectricity (30.5%) and photovoltaics (1.5%). The country aims to significantly boost its renewable energy share to 80% by 2030.

As the population increases by 3% annually[21] the future demand for electricity will put increasing pressure on the already struggling production capacity. This heightened demand may also impose a significant financial strain on JIRAMA and public finances, especially since the energy sector currently relies on substantial subsidies that account for 4.8% of the State budget.[22]

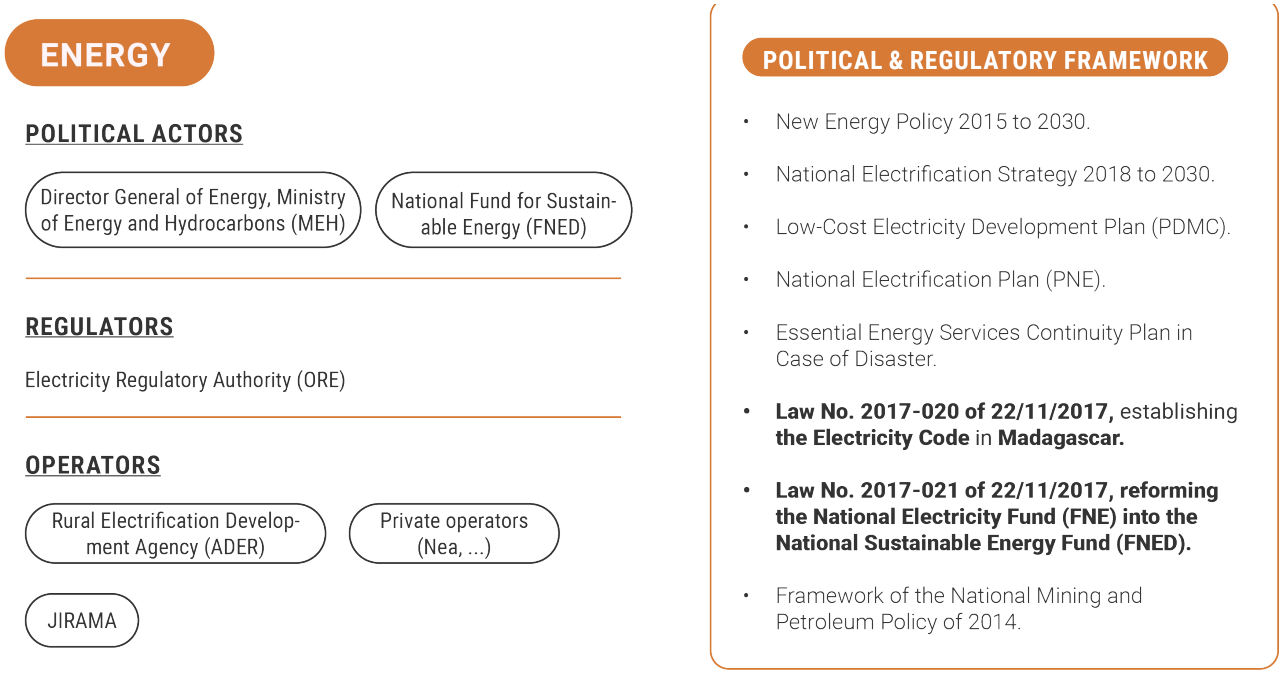
19. World Bank Energy Access Survey, Multi-Tier Survey, carried out in 2020
20. Madagascar – Economic Memorandum, World Bank, 2020
21. INSTAT – Demographic Projection of the Final Results of RGPH-3
22. Supplementary Budget Act, 2018

STAKEHOLDERS AND REGULATORY FRAMEWORK

POLITICAL DECISION-MAKERS	• **The Ministry of Energy and Hydrocarbons (MEH)** outlines Government policy, ensures strategic coordination of the energy sector and supervises the operations of JIRAMA. • The Agence de Développement de l'Electrification Rurale (ADER) is responsible for rural electrification. It has financed approximately 157 private-sector mini-grids across 400 localities.
REGULATOR	• **Electricity Regulatory Office - Office de Régulation de l'Electricité (ORE)**
OPERATORS	• **Jiro sy Rano Malagasy (JIRAMA),** Madagascar's national water and electricity company, holds a monopoly on power transport and distribution, primarily serving major population centers such as Antananarivo, Toamasina, and Fianarantsoa, while also maintaining 95 isolated networks across the country. • A major transmission network project (Projet d'Interconnexion et de Renforcement des Réseaux de Transport d'Energie Electrique à Madagascar, **PRIRTEM**), financed by AFDB and other partners, is currently being implemented.
PRODUCERS	Private Independent Power Producers (IPPs) such as HFF, HYDELEC, and ERMA supply electricity to JIRAMA through power purchase and lease agreements. JIRAMA's total installed generating capacity in 2021 was estimated at 672 MW—where 210.6 MW is directly owned by JIRAMA, and 461.4 MW is managed by the private sector. In areas beyond JIRAMA's service coverage, around 157 private sector mini-grids, with 119 fully operational, along with various companies providing off-grid solar systems(OGSs)[23], help meet the energy needs of local populations. The country's five largest power plants collectively contribute over half of the country's installed generation capacity and are critical infrastructure systems for the country: • **Coal:** The Ambohimanambola thermal power plant, with a capacity of 120 MW, serves as the primary electricity source for Antananarivo's interconnected grid • **Petroleum:** • **Hydro:** Following a fire in January 2022, the Andekaleka hydroelectric power plant (120 MW) is facing outage challenge • **Solar:** NEA (New Energy Africa NEA), which is part of Axian group, operates across more than 30 localities, contributing 100 MW of capacity, including 40 MW from the Ambatolampy solar power plant. Several large-scale projects are planned for the future, including the Volobé dam by the Compagnie Générale d'hydroélectricité (120 MW) and Sahofika dam (205 MW).

23. World Bank project document

Figure 11: Overview of the Institutional and Policy Framework related to Infrastructure Resilience in the Energy Sector

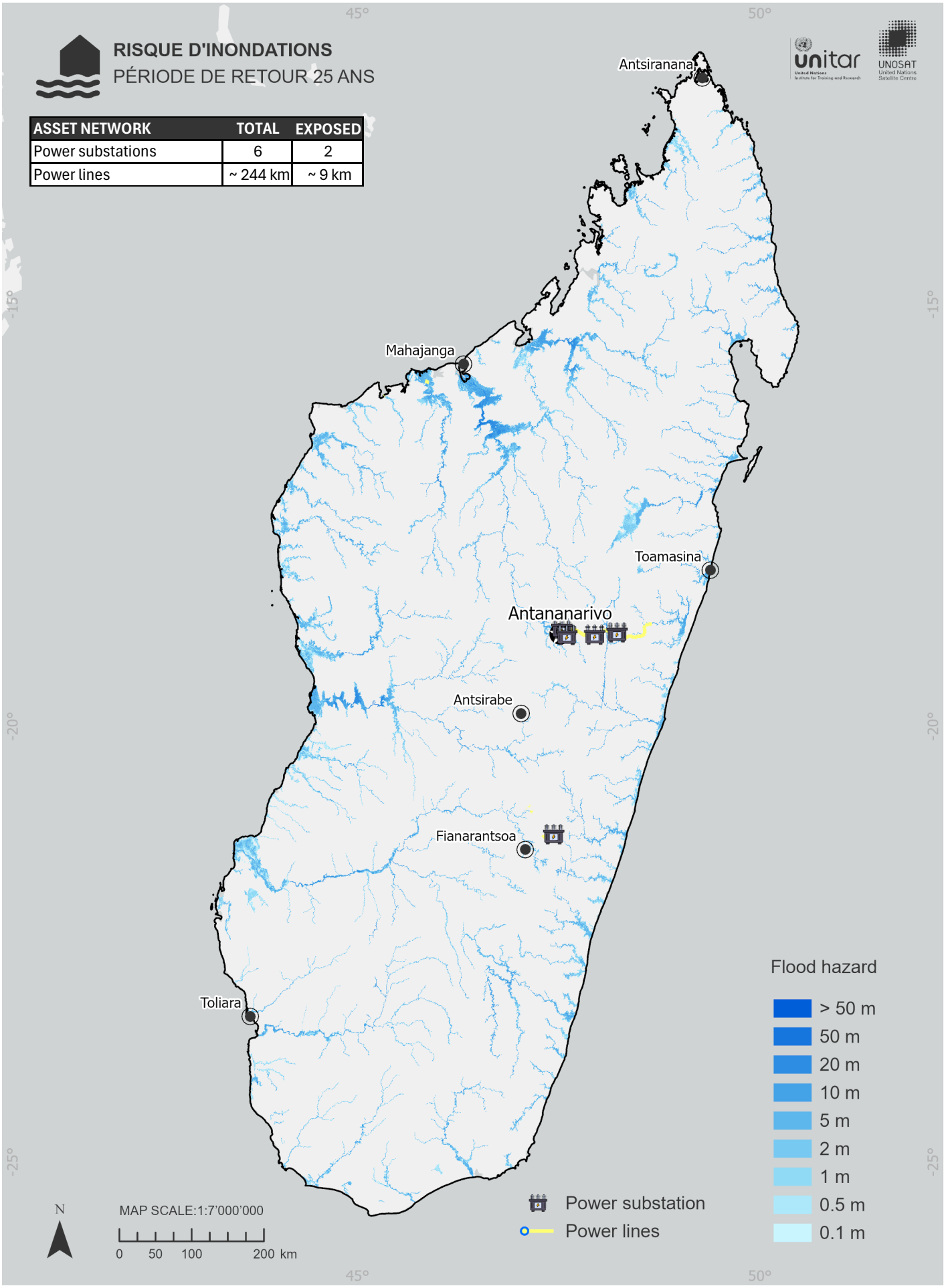


Source: Authors

DISASTER RISKS

Climatic hazards pose significant challenges to Madagascar's power transmission and generation. Extreme weather events like heavy rains and cyclones cause dam overflows and landslides that damage hydroelectric infrastructure and transmission lines. These climatic episodes lead to widespread and costly power outages. Power lines are particularly vulnerable to high winds, which frequently result in widespread service interruptions. In particular, during periods of elevated water levels, as shown on Map 5 below, approximately two of six power substations and around nine kilometers of power lines are particularly at risk.

Map N°5. Flooding Risks for Power Transmission Infrastructure



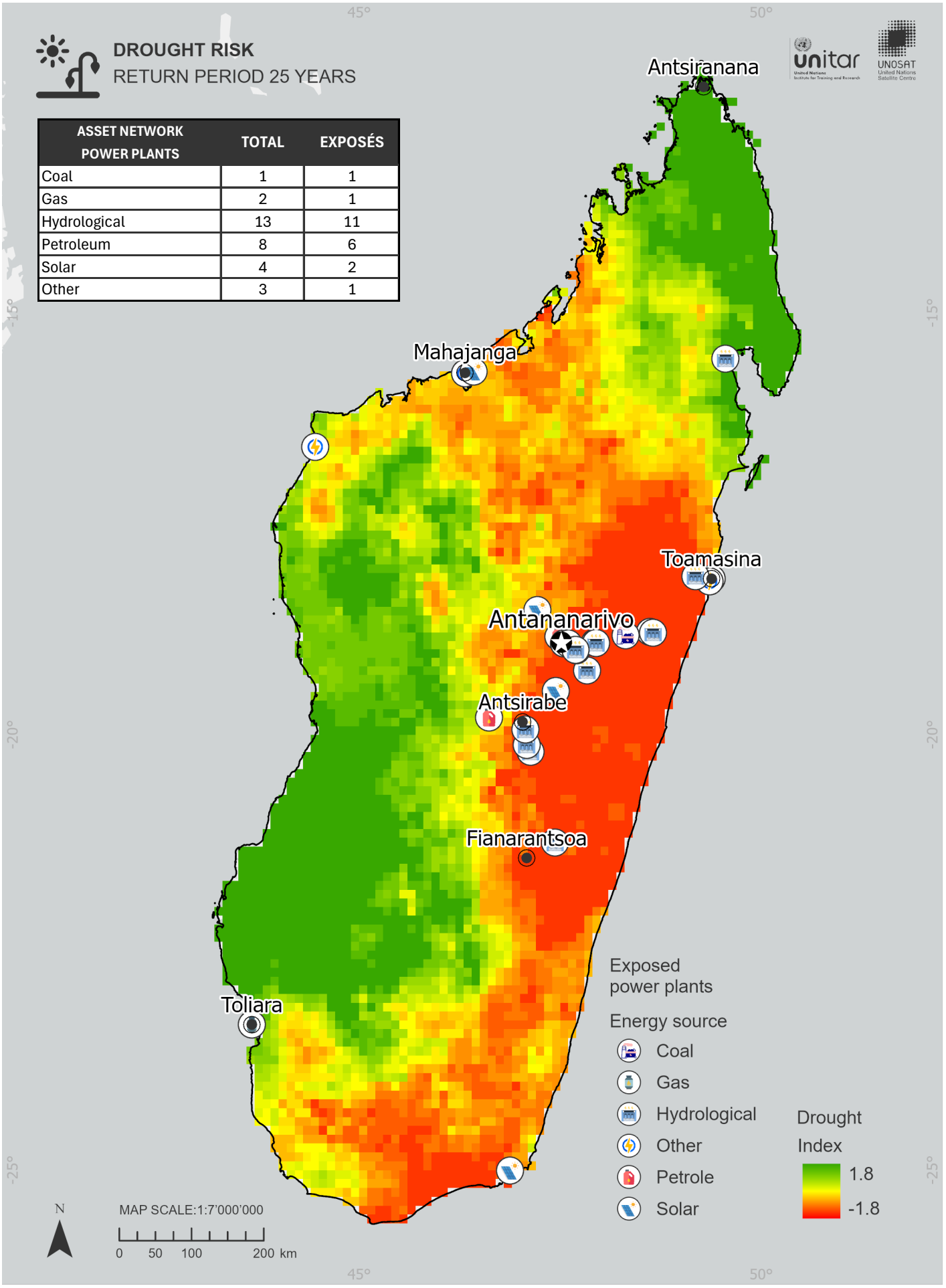
Additionally, earthquakes, although often of low magnitude, can damage power infrastructure located near their epicenters.

Cyber-attacks also threaten the security of electrical systems, while **droughts** and **fires** significantly impact water supplies, leading to decreased hydropower production (see Map 6).

The analysis of Map 6 reveals that 22 assets are potentially at risk from drought, as they are located in areas classified as dry. Map 6 shows the Standardized Precipitation Index (SPI), which reflects precipitation conditions over a three-month period, supplemented by Integrated Multi-satellite Retrieval (IMERG) data from the Global Precipitation Measurement (GPM) mission, providing a comprehensive overview of potential dry and wet conditions over a 25-year return period. Positive values on the map (ranging from 0 to 1.8) indicate wet conditions, while negative values (ranging from -1.8 to 0) highlight dry conditions. The SPI index is a widely recognized tool for characterizing meteorological dryness on different time scales.

Photo by EVANI Эвани: https://www.pexels.com/photo/cityscape-of-antananarivo-in-summer-18870790/

Map N°6. Power Generation Infrastructure Exposed to Drought



ASSET NETWORK POWER PLANTS	TOTAL	EXPOSÉS
Coal	1	1
Gas	2	1
Hydrological	13	11
Petroleum	8	6
Solar	4	2
Other	3	1

RESILIENCE MEASURES

The New Energy Policy (NPE) for 2015-2030 seeks to develop robust electricity infrastructure and provide affordable energy while also enhancing Madagascar's natural capital. Central to this policy is the commitment to ensure sustainable energy access for all through infrastructure projects funded by the national sustainable energy fund (Fonds National de l'Énergie Durable, FNED), which was established under the reform of Law 2017-021. The NPE emphasizes improved access to modern energy solutions, with the National Electrification Strategy (SNE) aiming to achieve a 70% household electrification rate by 2030.

A key element of the NPE is the integration of disaster risk management into the energy sector, by implementing measures to mitigate potential impacts on vulnerable infrastructure. This regulatory framework encourages the adoption of renewable energy sources to decrease reliance on traditional, less sustainable energy options.

To address climate risks and extreme events, Madagascar has developed an Essential services continuity plan, which encompasses the distribution of electricity, wood energy, and petroleum products during disasters. This plan outlines specific actions for disaster prevention and management.

Despite these legislative and strategic initiatives, the resilience of energy infrastructure remains inadequately addressed, largely due to challenges in effective policy implementation, securing adequate financing, and ensuring ongoing maintenance. Limited financial resources, along with insufficient institutional capacity and technical hurdles, create significant barriers that hinder the full realization of resilience objectives, thus compromising the energy sector's resilience to shocks and crises.

In 2019, **the energy sector reform support program (Programme d'appui à la réforme du secteur de l'énergie, PARSE) was launched to enhance JIRAMA's services through improved governance and financial management.** The program freed up resources by reducing State subsidies to JIRAMA. This effort was supported the World Bank-funded PAGOSE project, aimed to strengthen the financial and operational sustainability of the electricity sector while improving the quality of services provided by JIRAMA. In 2022, Madagascar conducted a study on the political economy of energy sector reforms as well as on the Low-cost electricity development plan.

RECOMMENDATIONS FOR THE ENERGY SECTOR

The following practical recommendations emerge from the analysis.

Table 11. Recommendations for the Energy Sector

RECOMMANDATIONS	AXES	PRINCIPES	AGENCE RESPONSABLES	PARTENAIRES POTENTIELS	PRIORITÉ	DÉLAI
Update and map the current state of existing energy infrastructure. This analysis should encompass an assessment of the vulnerability and resilience level of these infrastructure systems to identify most at-risk areas and prioritize interventions.	1. Data, Monitoring and Evaluation	P5.6	Ministry of Energy + CPGU	UNOSAT, UNITAR, UNDRR, CDRI	High	Medium-term
Strengthen and update data in the structure dedicated to monitoring and evaluating the various reforms, projects and policies conducted in the energy sector to determine their effective impact	4. Governance and Coordination	P5.4	MEH (Lead), MDPT, CPGU	UN Agencies, Development Banks	High	Medium-term
Design a standard that integrates resilience into energy policies, both in the use of renewable energies and in the construction and maintenance of electricity production and transmission infrastructure.	5. Policies, Standards and Regulations	P2.1	CPGU (Lead), MEH, ADER, JIRAMA	UNOPS, European Union, World Bank, AFDB, UNDP, USAID, UNDRR	High	Medium-term
Increase investment and public-private partnerships for developing resilient, integrated energy systems that combine renewable energy sources (solar, wind, hydro) with energy storage solutions. These systems should have the capacity to operate autonomously during main grid disruptions and to adapt to local conditions and weather forecasts.	3. Infrastructure Projects (Structural Measures)	P2.8	Ministry of Energy	European Union, World Bank, AFDB	High	Long term
Request information and best practices sharing about disaster risk management strategies in the energy sector from private operators.	2.Capacity Building	P2.8	Ministry of Energy, PSHP	Private operators	High	Long term

C. TELECOMMUNICATION

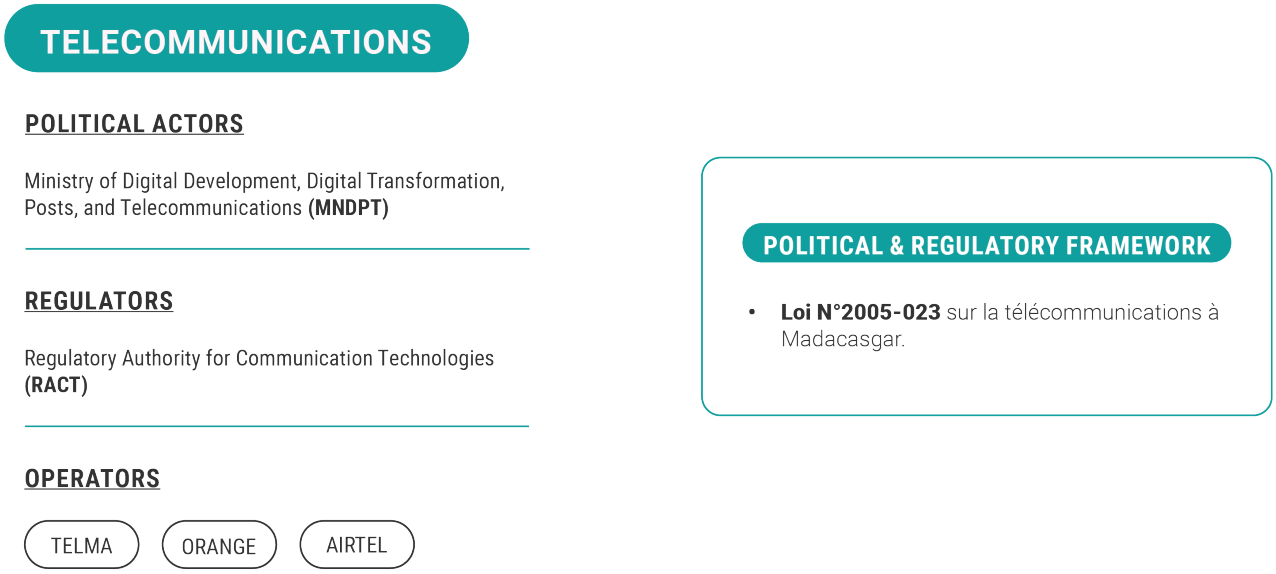
As of 2021, internet usage in the country reached approximately 22% of the population, with broadband access extending to over 900 municipalities. Local operators are striving to enhance network coverage across the country. Nevertheless, significant challenges persist in terms of accessibility and service quality, particularly in rural areas.

Madagascar's ICT sector is experiencing significant growth, with over 400 companies contributing to this sector of the economy.

STAKEHOLDERS AND REGULATORY FRAMEWORK

POLITICAL DECISION-MAKER	• **Ministry of Digital Development, Digital Transformation, Post and Telecommunications (MNDPT)**
REGULATOR	• **The Autorité de Régulation des Technologies de Communication (ARTEC),** under the aegis of the MNDPT, is responsible, among other things, for granting licenses, managing resources, protecting users and ensuring fair competition.
OPERATORS	• **Three operators** – Telma (historical operator), Orange and Airtel – vie for dominance in mobile services. However, there is a monopoly on fixed-line services and the cable network (only 10,000 km of fiber optics), and a duopoly on international infrastructure.

Figure 12.: Overview of the Institutional and Political Framework related to Infrastructure Resilience in the Telecommunications Sector



Source: Authors

DISASTER RISKS

In Madagascar, climatic hazards significantly challenge the resilience of telecommunications infrastructure systems, exposing their vulnerabilities. Cyclones, which carry intense winds and heavy rains, frequently inflict serious damage to telecommunications towers and cable networks.

Map 7 shows the exposure of ICT infrastructure to flooding caused by cyclones or heavy rains. 261 of the 3,904 recorded wired assets (against 313 of the 4,002 recoded wireless services) are at risk. Based on GDP estimates, the 261 exposed wired services are crucial for providing Internet access to over 879,108 individuals.

Other hazards have the capacity to disrupt telecommunications services. Fires—both urban and wildfires—and floods can cause breakdowns and service interruptions, jeopardizing continuity of telecommunication services. Additionally, heat waves and droughts can lead to electrical voltage spikes likely to disrupt critical infrastructure. The interplay of these climatic events, alongside cybersecurity threats and pandemic challenges, highlights the need for enhanced resilience of communication systems to withstand the growing frequency and severity of potential disruptions.

RESILIENCE MEASURES

Currently, Madagascar lacks dedicated framework documents, such as National Plans for Emergency Telecommunications, focused on enhancing the resilience of telecommunications infrastructure, as recommended by the International Telecommunication Union (ITU). While there are multi-sectoral emergency plans, their integration into formal sectoral strategic documents is essential for improving planning and coordination, ultimately optimizing disaster response efforts.

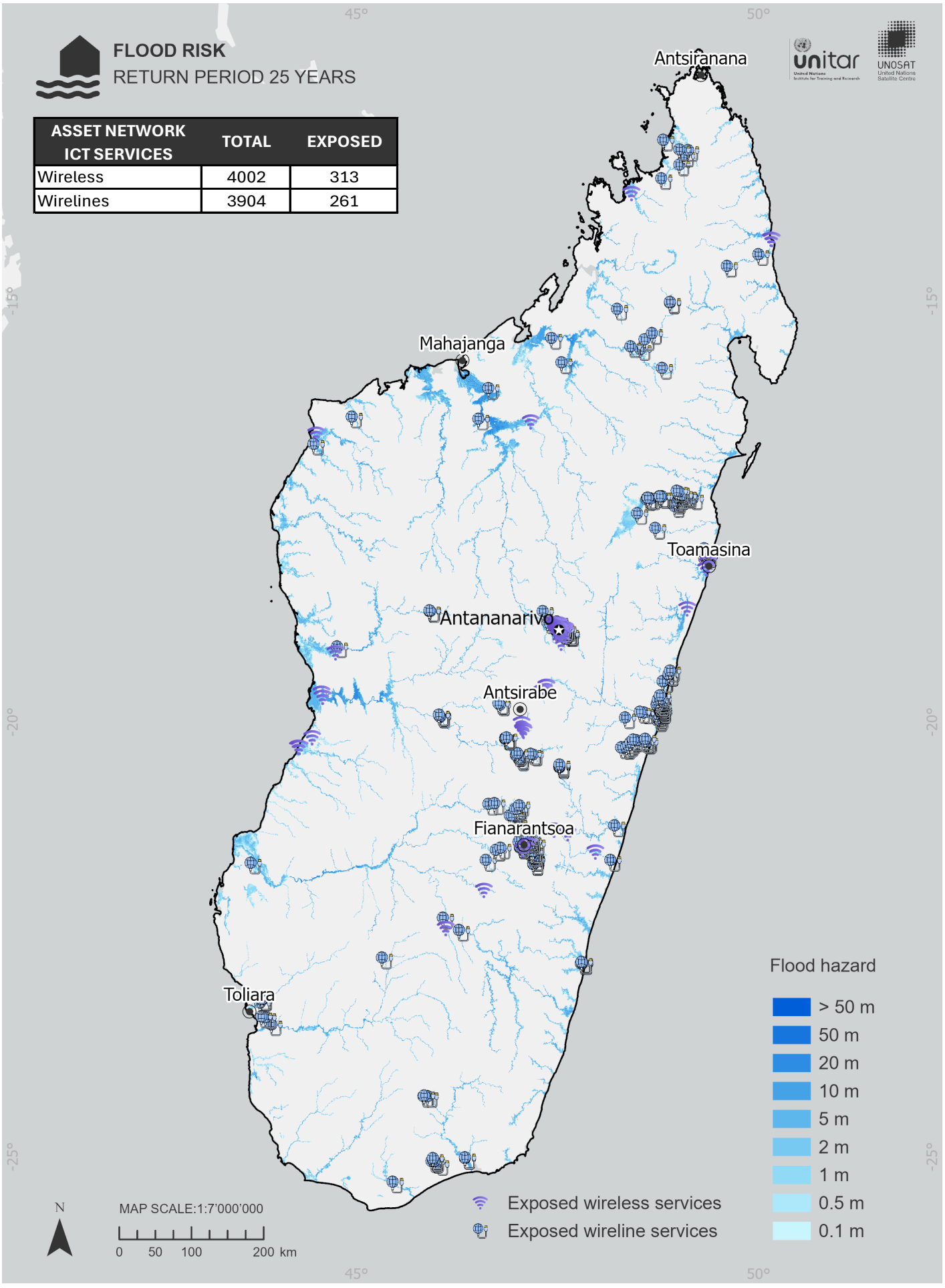
The telecommunications sector is vital for Madagascar's resilience against cyclones and floods. The Early Warning System (EWS) coordinated by the national risk and disaster management office (Bureau National de Gestion des Risques et des Catastrophes, BNGRC) relies on data from the General Directorate of Meteorology (DGM) and disseminates warnings through local radio, the Internet, and SMS. The EWS is supported by private sector subsidies and is designed to facilitate rapid and effective communication, which is crucial for coordinating relief efforts, disseminating vital information, and managing response operations. Telecommunications technologies provide the population with quick access to alerts and safety instructions, helping to save lives and mitigate damage.

In terms of international connectivity, the sector has proper redundancy in place and is relatively well-protected, with three active submarine cables and three strategically located landing stations, alongside a fourth cable planned for the future. Telma, the former incumbent, is a landing party for the EASSy and METISS cables, while Orange handles LION. The connection of the new 2Africa cable in 2023 promises further enhancements to international connectivity.

However, the lack of open-access cables and the effective duopoly of Telma and Orange limit price competition in the market.

Photo by Lara Jameson: https://www.pexels.com/photo/magnifying-glass-on-a-map-8828322/

Map N°7. ICT Infrastructure Exposed to Flooding



RECOMMENDATIONS FOR THE TELECOMMUNICATIONS SECTOR

The following practical recommendations emerge from the analysis.

Table 12. Recommendations for the Telecommunications Sector

RECOMMENDATIONS	FOCUS AREAS	PRINCIPLES	ENTITIES INVOLVED	POTENTIAL PARTNERS	PRIORITY	TIMELINE
Enhance the capacity of the emergency works unit and improve the availability of alternative solutions to ensure uninterrupted service delivery during breakdowns.	3.Infrastructure Projects (Structural Measures)	P6.2	ARTEC	Telecom Operators	Moderate	Short-term
Facilitate exchange of information about disaster risk management strategies and practices with private operators to strengthen the capacity of Ministry staff.	1.Data, Monitoring and Evaluation	P1.2, P1.3	MNDTP ARTEC	Telecom Operators	High	Medium-term

D. WATER AND WASTEWATER

Water is a critical resource underpinning various sectors in Madagascar. Approximately 15,518 hm^3 of water are utilized annually, of which 5,470 hm^3 for hydroelectric production, equating to 4.5% of the country's available natural resources. The agricultural sector is another dominant user of water resources, surpassing urban consumption and industries like textiles and mining.

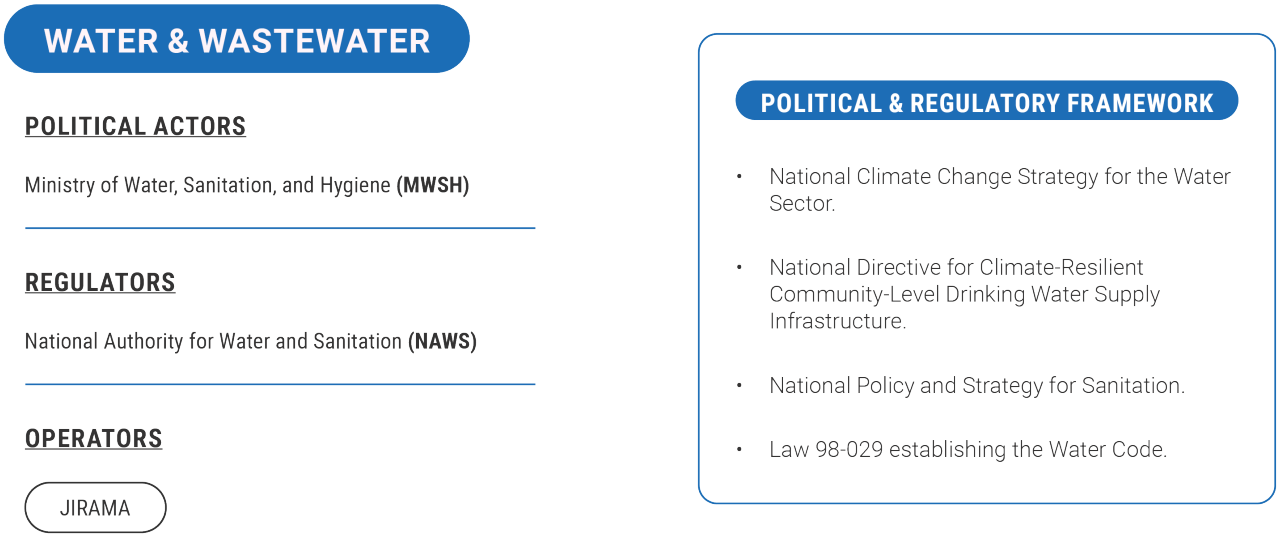
The water and sanitation situation in Madagascar remains critical, especially in the South where approximately 60% of the population lacks access to safe drinking water and adequate sanitation facilities. Climate change further exacerbates these issues by disrupting water supplies, negatively impacting agricultural productivity, and threatening food security.

STAKEHOLDERS AND REGULATORY FRAMEWORK

POLITICAL DECISION-MAKER	• **The Ministry of Water, Sanitation and Hygiene (MEAH)** is responsible for designing and implementing national strategies and policies aimed at improving access to drinking water and sanitation services, with the overarching goal of improving the well-being of the population and fostering economic growth. The ministry is specifically tasked with defining and implementing policies for the sanitation sector as a whole, and for coordinating the sector's activities.
REGULATORS	• The establishment of the regulatory body for water, sanitation and hygiene **(Organisme Régulateur de l'Eau, de l'Assainissement et de l'Hygiène)** is underway in Madagascar. This regulatory body will be responsible for ensuring compliance with established standards for water and sanitation services, while monitoring water resource tariffs, including charges and costs at the pump. • The national water and sanitation authority **(Autorité Nationale De l'Eau et l'Assainissement, ANDEA)** has the mission to manage and implement Madagascar's Integrated Water Resources Management (IWRM) policy by establishing guidelines for watershed stakeholders under master schemes and plans. Furthermore, it oversees the national water resources fund **(Fonds National sur les Ressources en Eau, FNRE)**, a participatory fund for water resource management activities, with a focus on protection, restoration and resource mobilization, and an emphasis on cross-sectoral aspects. However, the operational inactivity of ANDEA for several years raises concerns about its ability to fulfill its responsibilities, particularly the critical functions of issuing authorizations for water abstraction and wastewater discharge.

OPERATOR	**Jiro sy Rano Malagasy (JIRAMA)** is the national company responsible for supplying electricity and potable water in Madagascar, serving as a critical provider for 66 towns across the island.

Figure 13. Overview of the Institutional and Policy Framework related to Infrastructure Resilience for the Water and Wastewater Sector



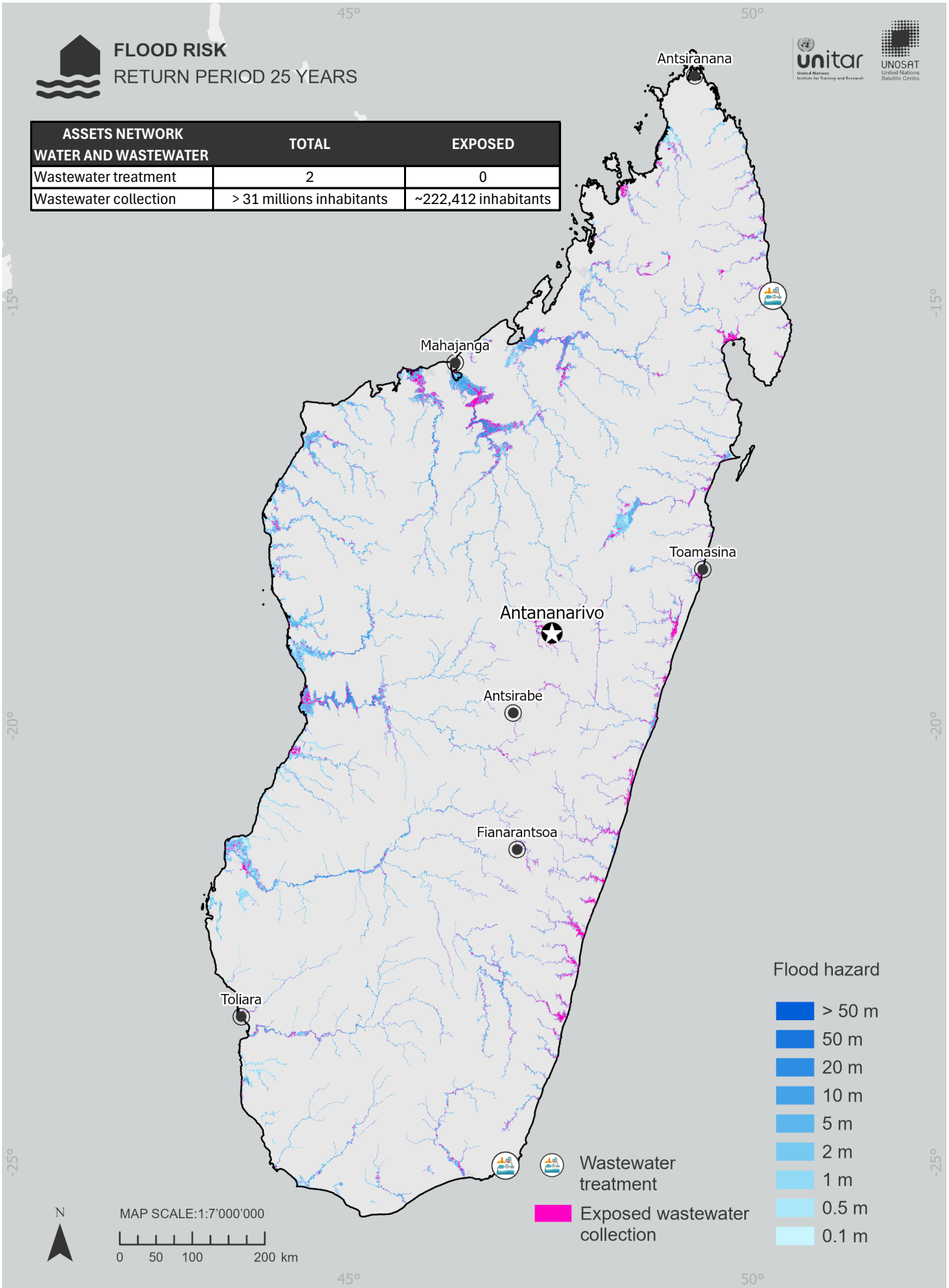
Source: Authors

DISASTER RISKS

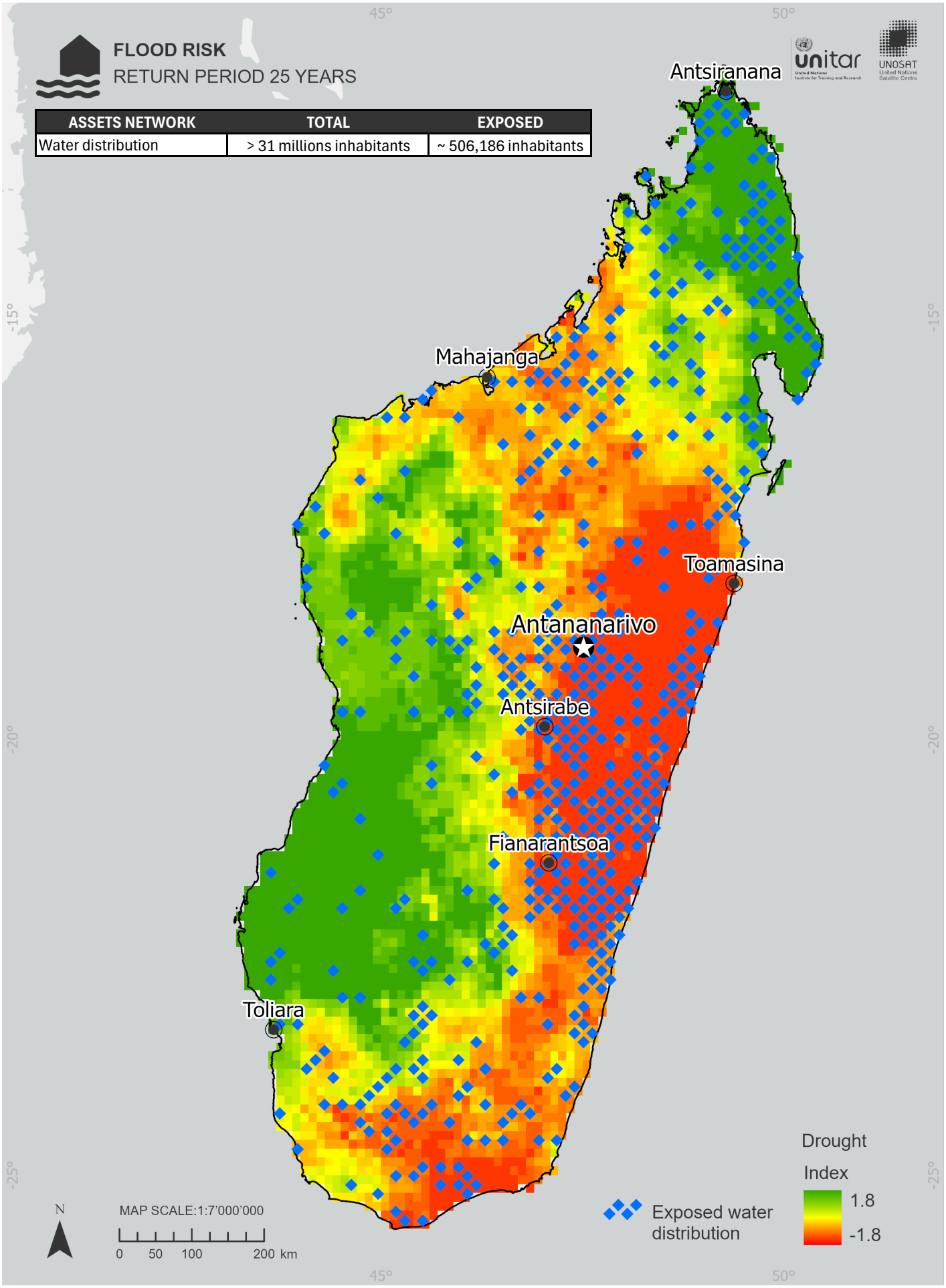
The main risks identified in this sector are cyclones, which cause flooding by overloading urban drainage systems, damaging infrastructure and complicating the management of stormwater. Furthermore, rising sea levels jeopardizes water supplies in coastal regions and exacerbates issues related to wastewater management.

Flooding heightens the risk of clean water contamination and complicates wastewater management, increasing the likelihood of pollution and disease spread. Map 8 shows a flood risk model available on CDRI's GIRI platform, combined with data on wastewater collection and treatment services. The analysis shows that approximately 222,412 people in Madagascar could be impacted by the flooding of wastewater collection services.

Map N°8. Wastewater Management Infrastructure at Risk from Flooding



Map N°9. Risk of Water Supply Interruption due to Drought



Heat waves lead to reduced water levels, intensifying pollution challenges in water sources. Map 9 shows the three-month accumulated Normalized Precipitation Index (SPI), combined with IMERG data from the GPM mission, which are used to estimate potential dry and wet conditions over a 25-year return period. Positive SPI values on the map (ranging from 0 to 1.8) indicate wet conditions, while negative values (ranging from -1.8 to 0) highlight dry conditions. The SPI index is a widely recognized tool for assessing meteorological dryness across various time scales. Data analysis established the exposure level of water distribution services to drought, which may affect approximately 5 million people in Madagascar.

Finally, **fires** disrupt water supplies as they require large quantities of water for extinguishment. **Seismic events** can damage water pipes and water treatment plants, heightening the risk of contamination of water sources. Finally, **structural failures** in water infrastructure can result in considerable interruptions to both water distribution and treatment processes.

RESILIENCE MEASURES

To address the above challenges, national policies and sectoral programs have been put in place. However, limited organizational, human, and financial capacities point out the need for improved governance and enhanced cross-sectoral coordination, particularly in the agriculture and energy sectors.

Current policies and regulations in Madagascar's water and sanitation sector play a crucial role in enhancing resilience to climate-related hazards. Law 98-029 (the Water Code) establishes a comprehensive framework for managing water resources as a public good. It promotes pollution prevention, regulates drinking water distribution while ensuring fair pricing. Decree No. 2015-104 sets forth construction standards for drinking water infrastructure designed to endure the impacts of climate change, thereby strengthening the resilience of community water networks.

The national strategy on climate change for the water sector (Stratégie Nationale sur le Changement Climatique pour le Secteur Eau), adopted in 2021, effectively integrates climate change adaptation into water resource management. It stresses the importance of institutional strengthening, capacity building, monitoring adaptation measures and promoting public-private partnerships.

The 2008 national sanitation policy and strategy (Politique et Stratégie Nationale pour l'Assainissement, PSNA) focuses on improving sanitation services and hygiene awareness while tackling issues related to under-funding and poor infrastructure quality. The national water and water sanitation policy (Politique Nationale de l'Eau et de l'Assainissement Hydrique, PNEAH), currently under development, seeks to ensure sustainable access to drinking water and sanitation for all by 2030, with a focus on effective resource management, hygiene promotion, and environmental responsibility. Moreover, in 2023, the Agence Française de Développement (AFD) implemented an integrated sanitation project in Antananarivo aimed at improving the city's sanitation and drainage systems, ultimately reducing flooding frequency and enhancing the overall sanitary environment for residents.

A significant advancement in the resilience of Madagascar's water sector is the inauguration of a new 180-kilometre pipeline[24] in the south of Madagascar, an area severely affected by drought and water shortages. Built through a collaborative effort between the Malagasy Government and UNICEF over two years, the pipeline is providing access to drinking water for 40,000 people, alleviating the need to travel long distances to collect water. The pipeline also contributes to improved health outcomes by decreasing waterborne illnesses such as diarrhea. The project has received support from the governments of Germany, Japan, the United Kingdom, and the United States.

RECOMMENDATIONS FOR THE WATER AND WASTEWATER SECTOR

The following practical recommendations emerge from the analysis.

Table 13. Recommendations for the Water and Wastewater Sector

RECOMMENDATIONS	FOCUS AREAS	PRINCIPLES	ENTITIES INVOLVED	POTENTIAL PARTNERS	PRIORITY	TIMELINE
Raise community awareness about hygiene and waste management in order to minimize the risk of flooding	2. Capacity Building	P4.4	MCC, ONG, APIPA	AFD	Moderate	Short-term
Enhance overflow detection and water flow monitoring systems through the acquisition of innovative equipment such as intelligent sensors and AI-driven predictive analysis tools.	2. Capacity Building	P1.2	MEAH, APIPA (lead), ANDEA, DGM, BNGRC	World Bank, CDRI, UNITAR, UNDRR	High	Short-term
Update existing urban planning documents and master plans to refine the assessment of investment needs in the sanitation sector, in light of the challenges posed by climate change and increasing demographic pressures. Ensure that these documents incorporate resilience criteria to anticipate future needs and risks.	5. Policies, Standards and Regulations	P2.8	MDAT, MEAH (lead), Communes, FTM	UNOPS, World Bank, European Union, UNDP, AFD, UNDRR	High	Medium-term
Conduct annual monitoring and assessment of the implementation of standards and master plans (national guidelines, PUDI)	1. Data, Monitoring and Evaluation	P1.3	MDAT, MEAH (lead), Communes	World Bank, European Union, UNDP, AFD	High	Medium-term
Set up infrastructure maintenance structures and systems as well as evacuation systems.	3. Infrastructure Projects (Structural Measures)	P2.7	MEAH/ JIRAMA/ APIPA	UNOPS, World Bank, European Union, UNDP, AFD	Moderate	Long-term
Invest in rainwater and wastewater recycling (e.g. Impluvium) and waste recycling (circular economy) systems to mitigate flooding risks	3. Infrastructure Projects (Structural Measures)	P2.8	MEAH/ JIRAMA/ APIPA/SENVH	World Bank, European Union, UNDP, UNOPS, AFD	Moderate	Long-term

24. Turning on the tap in Madagascar | UNICEF / https://www.unicef.org/stories/madagascar-daily-search-water-replaced-turning-tap#:~:text=The%20new%20water%20pipeline%20will,fetch%20water%20for%20her%20family

RECOMMENDATIONS	FOCUS AREAS	PRINCIPLES	ENTITIES INVOLVED	POTENTIAL PARTNERS	PRIORITY	TIMELINE
Invest in the upgrade of existing resilient water management infrastructure	3. Infrastructure Projects (Structural Measures)	P2.8	MEAH, JIRAMA	World Bank, AFD, AFDB, European Union	High	Long term
Re-establish and strengthen network connections, especially in high-rise areas, to reduce dependency on delivery by trucks	3. Infrastructure Projects (Structural Measures)	P2.5	MEAH, JIRAMA	World Bank, European Union	High	Long terme

E. EDUCATION

The resilience of the education system is becoming a strategic priority for the Government in response to the growing vulnerability of infrastructure and populations to natural disasters.

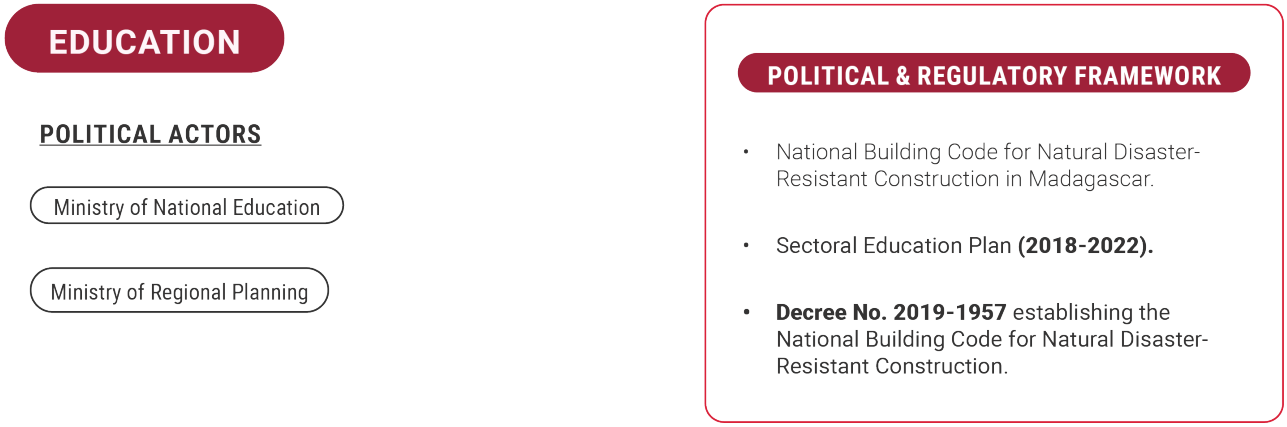
To address these challenges, several key initiatives have been put in place:

- **The construction of disaster-resistant school buildings** to guarantee sustainability of educational infrastructure against extreme climatic events.
- **Concurrently, disaster management in school setting is optimized through the establishment of local disaster management committees** to ensure the delivery of swift and coordinated responses when crises occur.
- **By integrating disaster risk reduction into school curricula, students are educated from an early age on the importance of preparedness.** Furthermore, the provision of training to educational staff in risk management enables to equip them with essential skills to manage emergency situations effectively.
- **Lastly, strengthening risk monitoring and assessment capabilities enhances the education system's ability to anticipate and mitigate the impacts of potential disasters.**

These combined actions are fundamental to ensuring a safe and sustainable educational environment in the face of disaster challenges.

STAKEHOLDERS AND REGULATORY FRAMEWORK

Figure 14. Overview of the Institutional and Political framework related to the Education Sector



Source: Authors

DISASTER RISKS

Every year, schools suffer significant damage, often resulting in temporary or permanent closure. Being located in a cyclonic zone, Madagascar is highly vulnerable to the impacts of climate change. Flooding due to rising water levels in rural areas can significantly disrupt access to schools, particularly in regions intersected by several rivers. The interruption of schooling not only hinder academic progress but also create challenges for schools that struggle to manage these crises.

Disasters intensify existing socio-economic disparities, disproportionately impacting disadvantaged and vulnerable populations who are the most affected by these disruptions.

RESILIENCE MEASURES

Technical standards have been established for various construction projects, documenting requirements for the siting, design, dimensioning and construction of buildings to withstand adverse effects. Strategic Area 6 of the education sector program (Programme Sectoriel Éducation, PSE) aims to improve the resilience of the education system to risks and disasters. This is achieved by mitigating the risks from natural or man-made hazards, and by strengthening the resilience of the education system through a series of measures encompassing the entire system.

The initiative for the construction and rehabilitation of school buildings complying with the “national standard for building construction resistant to natural hazards” was targeted at coastal regions with previously low school enrollment rate. This effort has resulted in a notable rise in school attendance nationwide.

Schools built to withstand cyclones have evolved into vital community centers, serving as meeting places and shelters before, during and after cyclones. They also contributed to an increased

awareness and understanding of disaster risk among local communities. As a result, these schools are now positioned to take on a pioneering role in integrating disaster risk reduction into primary and secondary school curricula.

RECOMMENDATIONS FOR THE EDUCATION SECTOR

The following practical recommendations emerge from the analysis.

Table 14. Recommendations for the Education Sector

RECOMMENDATIONS	FOCUS AREAS	PRINCIPLES	ENTITIES INVOLVED	POTENTIAL PARTNERS	PRIORITY	TIMELINE
Update the DRM manual to incorporate the concept of infrastructure resilience, and explicitly include the concept of infrastructure resilience for the education sector.	5. Policies, Standards and Regulations	P5.1	Ministry of National Education (MEN)	UNDP, UNICEF, UNESCO, UNDRR, UNITAR	High	Medium-term
Contribute to CPGU Risk Atlas bulletin, which provides information on exposure levels to the general public.	1. Data, Monitoring and Evaluation	P4.2	CPGU, BNGRC	UNICEF, UNESCO	Moderate	Medium-term
Widely disseminate traditional hut construction standards for community buildings.	5. Policies, Standards and Regulations	P5.1	MEN, SENVH	World Bank, UNICEF, AFDB, UNHabitat, PHSP, USAID, BAD, Save the Children	Moderate	Medium-term
Increase investments in drinking water, hygiene, and sanitation infrastructure, alongside investments in solar and renewable energy systems in public schools and expand them to all regions to improve access to these essential services.	3. Infrastructure Projects (Structural Measures)	P2.8	Ministry of National Education (MEN)	UNICEF, World Bank, European Union, USAID	Moderate	Long-term

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APPENDIX I: STRESS-TESTING ANALYSIS RESULTS

Note: The scores, which are derived from consultations conducted throughout the project, are inherently subjective.

	AIR	RAIL	ROAD	MARITIME	ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE TRANSPORT SECTOR
Cyclones	5	3	5	3	Cyclones in Madagascar bring torrential rains and strong winds, damage roads and bridges, further isolate communities and disrupt supply chains. Railway bridges are particularly vulnerable to foundation erosion, leading to structural failure and frequent disruptions in transport networks. Cyclones also increase the likelihood of landslides, exacerbating infrastructure damage. High winds and heavy rains caused by cyclones inflict severe damage on airport facilities and disrupt their operations. Port infrastructure, such as cranes, is also vulnerable. A notable instance is cyclone Enawo, which rendered the port of Antalaha inaccessible for a week (BNGRC,2017).
Pandemics	5	1	4	2	Public health crises, particularly pandemics, result in travel restrictions and quarantine measures that critically disrupt airport operations. The reduced demand for travel via road, rail, and sea during such crises leads to a contraction in economic activities, prompting necessary adjustments to maintain connectivity and the functionality of transport systems. Additionally, the loss of revenue due to lockdowns and restrictions often hampers maintenance efforts, exacerbating existing maintenance issues.
Floods	2	1	5	3	Floods periodically entail road closure, railroad instability, and bridge destruction, which isolate communities, disrupt local economies and hinder access to basic services, particularly in rural areas. Additionally, floods can inflict severe damage on port infrastructure, including docks and warehouses, disrupting critical services and slowing the supply chain of critical goods. Similarly, flooding of runways, terminals and other facilities due to heavy rains or storms, can also disrupt airport operations.
Construction/ Structural failures	3	2	4	2	In Madagascar, corruption and substandard construction practices are primary contributors to structural failures, resulting in accidents and deteriorating infrastructure. These issues are exacerbated by inadequate maintenance.
Rising sea levels	0	0	2	3	As sea levels rise, ports and waterways may become flooded, thus complicating their operational functions. Similarly, rising sea levels increase the vulnerability of coastal roads to erosion and flooding, which results in higher maintenance costs and threatens the stability of coastal infrastructure.
Heatwaves / Drought	0	0	2	1	Heat waves and drought lead to road cracking and subsidence, which accelerate deterioration and disrupt freight transport, while also stressing road infrastructure and related services. Lack of water can also limit navigability in some waterways. Additionally, extreme heat causes the expansion and softening of airfield pavements, complicating the operation of airport infrastructure, including air conditioning systems and electrical components, and posing challenges for ground support operations (e.g. aircraft maintenance).
Earthquakes	0	1	1	1	While generally low in intensity, earthquakes can still inflict damage on roads and bridges, creating dangerous or impassable conditions due to cracks and subsidence. Buildings, runways and other critical infrastructure assets may also be affected. However, the risk posed by earthquakes is considered relatively low, as seismic events are generally of low intensity.

	AIR	RAIL	ROAD	MARITIME	ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE TRANSPORT SECTOR
Cyberattacks	2	0	0	1	Cyberattacks and computer failures can disrupt airport operations, jeopardize sensitive data, and introduce security risks. Similarly, since communication and surveillance in waterways are digital, such threats could interrupt maritime transport, particularly affecting international shipping. However, at the national level, the overall risk is considered relatively low.
Fires (urban, forest fires, bush fires)	0	0	0	1	Vegetation fires pose a risk to road and rail transport by reducing visibility due to smoke, entailing road or track closure, and causing potential damage to infrastructure such as bridges and railroads. In the case of maritime and air transport, smoke can disrupt navigation and flight plans, while fires may damage warehouses, buildings and other critical facilities. Nonetheless, during project consultations, this risk was generally assessed as relatively low.

	WATER SUPPLY	WASTEWATER MANAGEMENT	ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE WATER SECTOR
Floods	5	5	Flooding involves the risk of contamination of clean water by wastewater, which adversely affect various sectors reliant on these resources. Moreover, the complexity of wastewater management escalates during flooding events, heightening the risk of overflows and pollution. This can exacerbate flood conditions, further polluting water sources and increasing the potential for disease spread.
Cyclones	5	5	Heavy rains and storm surges can overwhelm urban drainage systems that are often insufficient, causing flooding and infrastructure damage. This overload restricts the drainage systems' capacity to manage stormwater efficiently, leading to persistent water accumulation issues and damage to facilities.
Rising sea levels	5	5	Rising sea levels pose a threat to water supplies in coastal areas prone to marine flooding, such as Morondava and other coastal towns. Furthermore, rising sea levels threaten wastewater management in low-lying areas, increasing the risk of flooding.
Heatwaves / Drought	5	3	Heat waves can diminish or dry up water sources, potentially disrupting service provision across various sectors. Surface waters are particularly vulnerable to pollution and contamination when their levels decline.
Fires (urban, forest fires, bush fires)	4	4	Fires can disrupt water supplies as large quantities of water are required to extinguish them, whereas access to this resource remains difficult for users. Critical wastewater management infrastructure could be seriously affected by this hazard.
Construction/ Structural failures	4	4	Poorly designed and faulty infrastructure as well as substandard wastewater treatment facilities can cause interruptions in water distribution. Similarly, disruptions in wastewater treatment facilities can impact multiple economic sectors.
Earthquakes	2	2	Earthquakes can damage water pipes and water treatment plants, causing drinking water leaks and wastewater overflows. Such damage heightens the risk of contaminating water sources, potentially facilitating the spread of diseases, thus requiring rapid repairs to protect public health.

	WATER SUPPLY	WASTEWATER MANAGEMENT	ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE WATER SECTOR
Pandemics	1	1	Risk perceived as low
Cyberattacks	1	1	Risk perceived as low
Landslides	0	0	Heavy rains cause landslides that damage infrastructure and obstruct both natural and artificial drainage channels. The risk, however, is perceived as low.

	POWER GENERATION	POWER TRANSPORT	ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE ENERGY SECTOR
Floods	3	3	Oversized dams pose significant challenges for power generation and transmission due to outdated infrastructure that are not designed to manage increased water volumes. Furthermore, excessive water flows can overwhelm dam control capacities, resulting in uncontrolled spills and risks of damage to critical equipment.
Cyclones	3	5	Cyclones can cause dams to overflow and flood power stations. They can trigger landslides and damage power transmission infrastructure. The high winds brought by cyclones can wreak havoc on buildings, power lines, and other infrastructure. Transmission lines are vulnerable to high winds, debris and falling branches and trees. Widespread power outages occur when wooden towers and poles are damaged.
Construction/ Structural failures	5	2	Structural failures result in technical losses across the energy supply chain, impacting generation, transmission, and distribution segments. These losses arise from discrepancies between the energy produced and the energy that is ultimately distributed or consumed, often due to malfunctions, breakdowns, or planned load shedding[25] within transmission and distribution networks. These “dry losses” represent energy that is produced but not used, i.e. the energy not distributed.
Heatwaves/ Drought	3	0	Drought conditions lead to water scarcity, which affects urban water supply, hydroelectric power generation, cooling processes for thermal energy production, and wastewater management systems.
Landslides	1	3	Power generation can be obstructed by debris and blockages in watercourses caused by landslides. These geological events can damage power transmission and transport infrastructure, particularly affecting wooden poles and towers situated near landslide-prone areas.
Fires (urban, forest fires, bush fires)	2	2	Ashes and debris from fires can clog storage basins and reservoirs, leading to interruptions in water supply and reduced energy productivity. Additionally, forest fires can cause damage to water and power transport infrastructure, leading to disruptions in power generation and transport.

25. In the capital city, rotating load shedding occurs every day, with scheduled power cuts lasting several hours, especially between 2:30 and 5:00 pm and during nighttime hours. The Government has been discussing potential solutions to load shedding at cabinet meetings. The Government acknowledges the persistent electricity supply challenges and is working on several solutions to stabilize the grid. These include investing in energy infrastructure and implementing initiatives aimed at boosting local energy production.

	POWER GENERATION	POWER TRANSPORT	ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE ENERGY SECTOR
Cyberattacks	2	2	Cyberattacks enable hackers to compromise systems, damage equipment, or trigger power outages. These attacks can target sensitive information, including electrical network diagrams and security protocols, as well as confidential customer data from JIRAMA, including billing, consumption, and installation information.
Earthquakes	1	1	While earthquakes are typically of low magnitude in Madagascar, they can still affect power generation plants and power transmission infrastructure situated near epicentral zones.
Pandemics	0	0	
Rising sea levels	0	0	

ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE TELECOMMUNICATIONS SECTOR		
Cyclones	4	High winds and heavy rains can severely impact telecommunications installations, including pylons and cable networks.
Cyberattacks	4	Internet use could be affected in the event of a cyber security breach. Substantial losses can also occur in the event of data misappropriation, theft or loss.
Fires (urban, forest fires, bush fires)	3	Fires affecting telecommunications facilities can lead to breakdowns or interruptions in the supply of services.
Floods	2	Floods can cause damage to telecommunications network transport or distribution channels.
Heatwaves / Drought	2	Intense heat waves can trigger power surges that may damage electrical infrastructure and lead to disruption of telecommunications services.
Pandemics	2	During a pandemic, staff shortages can lead to increased bugs and the saturation of communication services and networks.

ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE TELECOMMUNICATIONS SECTOR		
Construction/ Structural failures	2	Structural failures can result in breakdowns and recurring service interruptions, which can have a cascading effect across multiple sectors, particularly in times of shock.
Earthquakes	1	While high magnitude earthquakes can disrupt international cables that carry internet networks, leading to service interruptions and breakdowns. However, Madagascar experiences this hazard relatively infrequently.
Rising sea levels	0	
Landslides	0	

ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE EDUCATION SECTOR		
Cyclones	5	Cyclones cause substantial damage to educational infrastructure assets, which exacerbates existing inequalities in education access. 9,271 children were unable to attend classes following cyclone Batsirai, as the cyclone damaged 211 schools (69 classrooms destroyed and 55 schools with torn-off roofs) (BNGRC, 2022). Such damage not only delays the learning process but also disrupts the school calendar. Furthermore, damaged roads further complicate access to schools that are still functional, creating additional hurdles for both students and teachers.
Construction/ Structural failures	5	Madagascar's education system faces significant deficiencies, including inadequate infrastructure, political instability, and regional disparities, all of which compromise the quality of education.
Floods	5	Floods damage school infrastructure, leading to closure of schools and disruption of classes. The displacement of families heightens the challenges of accessing education, and damaged roads and bridges further complicate access to schools.
Heatwaves / Drought	3	The drought in southern Madagascar, exacerbated by El Niño, is severely impacting education, as schools frequently close or suffer damage from extreme weather conditions. Many families, impoverished by the loss of crops, are compelled to withdraw their children from school to seek work or to relocate them. Furthermore, malnutrition and health issues stemming from water scarcity impair students' concentration and academic performance.
Fires (urban, forest fires, bush fires)	2	Fires, like those of 2020 in the Menabe region, destroy educational infrastructure and disrupt educational activities. Affected families are often forced to move or face economic losses, which in turn hinder their ability to keep their children in school, consequently reducing access to education.
Pandemics	1	The COVID-19 and past plague epidemics in Madagascar have disrupted the education sector, compounding pre-existing challenges. Extended school closures during the COVID-19 pandemic hindered learning and increased the risk of school dropout, especially in rural and vulnerable regions. Plagues outbreaks, such as the one in 2017-2018, caused school activity disruptions due to containment and quarantine measures, and exacerbated inequalities in access to education.
Earthquakes	0	

ANALYSIS OF RISKS POSED BY VARIOUS HAZARDS IN THE EDUCATION SECTOR		
Cyberattacks	0	
Rising sea levels	0	
Landslides	0	

APPENDIX II: REVIEW OF POLICIES AND INTEGRATION OF RESILIENCE PRINCIPLES

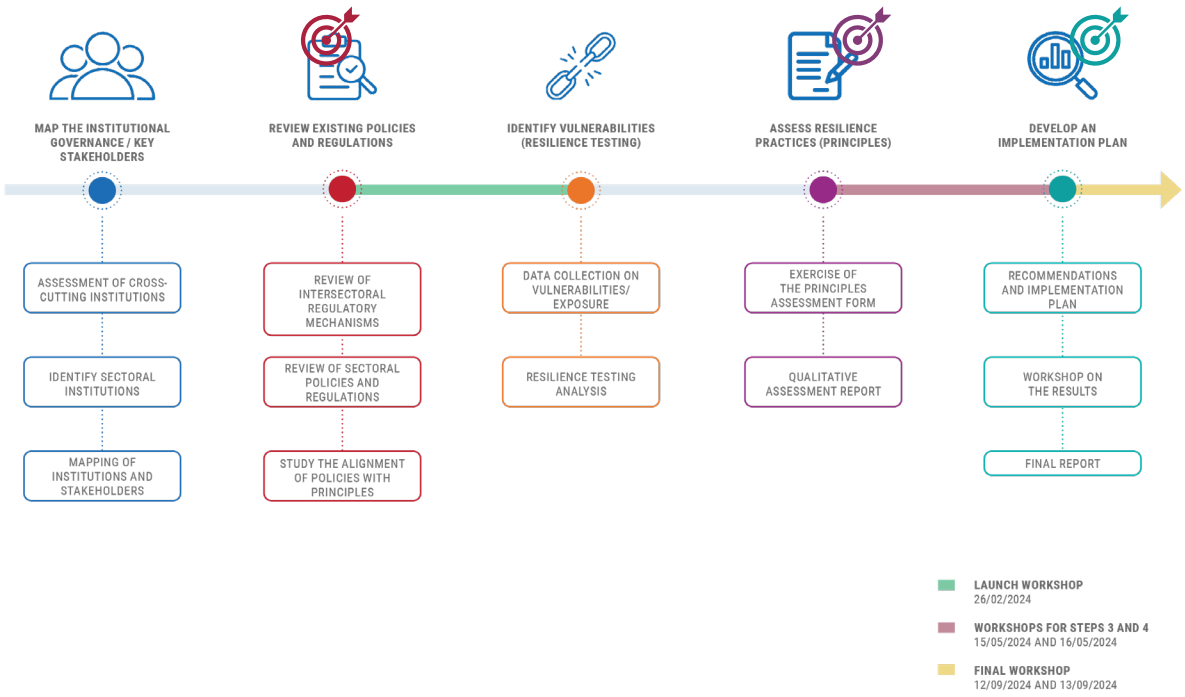
DOCUMENT TITLE	HOW IS THIS RELEVANT TO DRR OR RESILIENCE?	LINK WITH THE PRINCIPLES					
		P1	P2	P3	P4	P5	P6
CROSS-CUTTING ISSUES							
National Disaster Risk Management Policy	This document provides a framework for DRM/DRR activities at the national level. It specifies the key institutions involved and identifies government leaders tasked with coordinating each component DRM/DRR activities.	N	Y	N	Y	Y	Y
National Strategy for Risk and Disaster Management (Stratégie Nationale de la Gestion des Risques et des Catastrophes, SNGRC)	The main objective of the SNGRC is to establish DRM/DRR as a pillar of sustainable development by: • Ensuring effective integration of DRM/DRR into national and sectoral development policies, while strengthening the related legal and institutional frameworks. • Strengthening the technical, material and financial capabilities of institutions and other DRM/DRR stakeholders, based on a comprehensive knowledge of major risks and vulnerabilities across the country. • Further leveraging knowledge, innovation, and education to foster a culture focused on risk, security, and resilience at all levels. This can be achieved by supporting research initiatives, recognizing and valuing endogenous knowledge, and raising public awareness about the need for behavior change. • Integrating underlying risks into program/project design and implementation at both national and local levels. • Pursuing efforts aimed at improving technical tools for DRM/DRR, while building the capacity of stakeholders, and fostering greater resilience among the population. • Ensuring rapid recovery from disasters	Y	Y	Y	Y	Y	Y
National Adaptation Plan (Plan National d'Adaptation, PNA)	The National Adaptation Plan is structured around 3 strategic pillars: Pillar 1: Strengthen the governance and integration of adaptation Pillar 2: Implement a priority sectoral action program Pillar 3: Finance climate change adaptation	N	N	N	N	N	N

National Land Use Planning Policy (Politique Nationale de l'Aménagement du Territoire, PNAT)	The PNAT outlines 6 policy orientations: • Territorial efficiency: The PNAT seeks to ensure fair spatial allocation of activities, tailored to the unique needs and characteristics of territorial units, with a view to meeting the requirements of economic efficiency, particularly in terms of sustainable development, globalization, decentralized cooperation and opening up to new markets and partnerships • Regional development: Regional development should be strengthened through the transfer and reinforcement of skills, recognizing that Regions serve as optimal arenas for integrated land use planning policies, thereby supporting the implementation of the Government's decentralization and devolution policy. • Promotion of areas of significance: The PNAT is designed to be an opportunity to catalyze continued mobilization of development actors, in order to harness and enhance the potential of natural resources that support the promotion of areas of significance. • Sustainable management of natural resources: The PNAT is designed to promote effective management of the national territory, which takes into account the sustainable management of natural resources. • Urban development: Despite the existence of several regional urban centers, the country's urban geography is characterized by a concentration of influence in the capital city, whose demographic and economic weight is particularly significant. • Data and communication management: Data management is crucial in the process of developing territorial resources and potential (Regions, communes)	Y	N	Y	Y	Y	Y
ENERGY							
New Energy Policy (Nouvelle Politique Energétique, NPE)	The NPE advocates for the establishment of new energy infrastructure and encourages active participation in renewable energy from energy sector stakeholders, particularly operators. The objective is to ensure reliable energy supply, minimize the ecological impact of energy generation and consumption, enhance Madagascar's resilience to climate change, and create a favorable investment climate.	Y	Y	Y	Y	Y	N
TRANSPORT							
National standards applicable to road infrastructure resistant to floods and geological phenomena in Madagascar (Normes Nationales Applicables Sur Les Infrastructures Routières Résistantes Aux Inondations Et Aux Phénomènes Géologiques, NIRIPG), 2020	The NIRIPG standards are designed to enhance resilience and protection of infrastructure assets against climate and geological hazards, thereby guaranteeing their sustainability. They aim to establish guidelines encompassing track classification and detailed procedures for each phase—design, construction, maintenance, and monitoring—while incorporating environmental recommendations. Additionally, the NIRIPG promote understanding of natural hazards, risks, and geotechnical factors, setting forth technical requirements that prioritize environmental conservation. They underscore the importance of taking into account various technical parameters and areas of expertise to achieve sustainable and resilient infrastructure.	Y	Y	Y	Y	Y	Y

TLC							
Law 2005-023/ Law 2021-035	Law 2005-023, supplemented by Law 2021-035, supports the liberalization of the telecommunications and NICT sector and its integration on a global scale, while adhering with established technical and ecological standards. It promotes health and environmental protection and fosters collaboration in the area of infrastructure development.	N	N	Y	N	Y	N
WATER AND WASTEWATER							
Law 98-029 "Water Code", 1999	Law 98-029 regulates water resource management, including environmental protection.	N	N	Y	N	N	N
Decree 2015-104— National Guideline for Climate Resilient Drinking Water Supply Infrastructure at Community Level" (Directive Nationale pour des Infrastructures d'Alimentation en Eau Potable à l'Echelle Communautaire Résistantes aux Aléas Climatiques), 2015	The decree is designed to enhance the resilience of community drinking water supply networks against climatic hazards. It sets forth standards for the construction and extension of infrastructure under the drinking water supply network reinforcement program (Programme de Renforcement des Réseaux). The national guideline outlines construction regulations aimed at achieving robust networks that are able to withstand climate hazards, catering to communities of 50 to 1,500 people.	Y	Y	Y	Y	Y	N
National Strategy on Climate Change for the Water Sector (Stratégie nationale sur le changement climatique pour le Secteur Eau), 2021	The National Strategy on Climate Change for the Water Sector is designed to step up the fight against climate change and reduce the sector's vulnerability through five strategic pillars. It emphasizes the importance of ensuring universal access to water, improving the management of water resources, and fulfilling both national and international commitments related to sustainable development and climate change.	N	Y	Y	Y	Y	Y
National Sanitation Policy and Strategy (Politique et Stratégie Nationale pour l'Assainissement , PSNA), 2008	Madagascar's National Sanitation Policy and Strategy focuses on improving sanitation and hygiene nationwide by establishing a clear regulatory framework, improving service delivery, increasing public awareness of hygiene, and monitoring health and environmental conditions.	N	Y	Y	N	Y	N

APPENDIX III: CONSULTATIONS AND ACTIVITIES

The project's methodology comprises the following five steps:



Step 1. Map institutional governance and identify key stakeholders

The first step consists of mapping key stakeholders involved in disaster risk reduction and infrastructure development in each critical infrastructure sectors such as energy, transport, information and communication technologies (ICT) and water.

Step 2. Review existing policies and regulations

This second step assesses whether there are relevant policies and regulations that can influence the resilience of infrastructure systems, as well as their key disaster risk reduction (DRR) components. This involves analyzing both cross-cutting policies and specific sectoral policies.

The results achieved under Steps 1 and 2 were validated during a workshop held on March 26, 2024, with twenty-two (22) participants representing 10 institutions involved in promoting resilient infrastructure in Madagascar. Experts from the project's technical and financial partners, namely CDRI, UNDRR, UNOSAT and UNITAR were also in attendance.

Step 3. Detect vulnerabilities through a stress-testing analysis

The third step involves performing a multi-hazard stress-testing of infrastructure systems to evaluate their vulnerabilities. The objective is to assist countries in better understanding infrastructure vulnerabilities and system interdependencies. This allows countries to prioritize actions and resources while assessing the state of critical infrastructure nationwide.

Step 4. Assess current resilience through the Principles of Resilient Infrastructure

In this step, users of the methodology consider whether current infrastructure practices are adequate for achieving infrastructure resilience. This assessment is done through a workshop with relevant

key stakeholders identified in Step 2, and enables participants to familiarize themselves with the Principles of Resilient Infrastructure.

The tool used was an assessment questionnaire developed by UNDRR. The interactive workshop organized by the Emergency Prevention and Management Support Unit (Cellule de Prévention et d'appui à la Gestion des Urgences, CPGU) took place on May 15 and 16, 2024, in Andakana Anosiala, and allowed for interactive discussions with approximately thirty representatives from key ministries in Madagascar, including Public Works, Transport, Land Use Planning, Water, and Energy, along with various key DRM/DRR stakeholders.

The results, along with analysis from the preceding steps, are then used to prioritize key interventions and inform recommendations developed in Step 5. To refine these recommendations, interviews were conducted with stakeholders across relevant sectors.

Step 5. Develop an implementation plan and produce a final report

As a final step, the final report consolidates the analysis from the previous steps, including data from workshops. The main findings, recommendations and implementation plan then need to be shared and discussed with relevant stakeholders during a final workshop to validate the results. This workshop took place on September 12 and 13, 2024 in Antananarivo.

APPENDIX IV: RESILIENCE PRACTICES DASHBOARD

PRINCIPLES / ACTIONS / DESCRIPTIONS		IMPLE-MENTATION STATUS	PRIORITY	ANALYSIS / EVIDENCE
PRINCIPLE 1: CONTINUOUSLY LEARNING *UNDERSTAND AND MANAGE THE INTERDEPENDENCIES AND CORRELATIONS IN AN INFRASTRUCTURE NETWORK*				
P1.1. Expose and validate assumptions	Are threat and hazard modeling assumptions, which are used in plans and operating systems tested and verified for quality and reviewed after disruptions?	Moderate	High	The General Directorate of Meteorology (Direction Générale de la Météo, DGM) has implemented early warning mechanisms, which are systematically communicated to the structure in place within BNGRC. On a national scale, the national contingency plan (17 regions covered) is available. The SIMEX exercise is implemented through consensus among DRM stakeholders (CRIC members). Following a disaster, the eight sector groups hold a meeting to share lessons learned and best practices in view of integrating new insights into the updated contingency plan.
P1.2. Monitor and intervene appropriately	Do you have monitoring/data systems in place to intervene in real-time in your infrastructure?	Moderate	High	The early warning system lacks comprehensive coverage across all sectors and regions. The DGM has a national warning system in place and disseminates meteorological information—mostly related to areas affected by the hazard—countrywide.
P1.3. Analyze, learn and formulate improvements	Do you have formal mechanisms in place for disseminating/embedding lessons learned from past disruptions/disasters?	Moderate	Moderate	Contingency plans are based on historical data and suffer from a lack of systematic coverage across all sectors. Ongoing efforts to address the gap need to be strengthened.
P1.4. Conduct stress test	Do you carry out risk/scenario/ stress-testing analysis of existing systems?	Low	High	The existing regulatory and control structures are insufficient, underutilized, and not widely known.
PRINCIPLE 2: PROACTIVELY PROTECTED *DETERMINE AND INCREASE THE LEVEL OF HAZARD/THREAT PREPAREDNESS AND RESPONSE*				
P2.1. Raise essential safety requirements	Do new infrastructure systems and upgrades to existing infrastructure account for extreme but plausible lifecycle hazard scenarios and do they adopt elevated baselines for essential safety requirements?	Moderate	Moderate	Some programs are donor-dependent. In the education sector, newly built schools do not meet construction standards and do not take into account climate change considerations. The CPGU issued a decree in 2019 and published a multi-hazard standard for public infrastructure, for wide dissemination in all regions. It also conducted capacity building of technicians to monitor the application of these standards, but implementation remains inconsistent nonetheless.
P2.2. Exceed basic requirements for critical components	Do critical components of national infrastructure exceed basic reliability and durability requirements?	High	Low	Building construction standards typically vary based on the specific construction zone (coastal or plateau areas). The list of legal components is known and categorized.
P2.3. Consider complex interdependencies of connected networks	Are there alternative networks available to deliver the same or similar critical services?	Low	High	The telecommunications sector is characterized by recurrent interruptions. The energy sector is characterized by major interruptions to power supply and transport (as was the case during cyclone GAMANE). JIRAM'As efforts to restore power remain hindered by poor access, with some neighborhoods ("quartiers") having electricity a few hours a day only. With regard to water supply, water sources are not protected, raising the risk of contamination during adverse weather conditions, which can lead to further interruptions in service delivery.

PRINCIPLES / ACTIONS / DESCRIPTIONS		IMPLE-MENTATION STATUS	PRIORITY	ANALYSIS / EVIDENCE
P2.4. Embed emergency management	Are emergency management plans and responses properly funded, adequately resourced and frequently tested with appropriate stakeholders?	High	Low	The financing of emergency operations remains heavily dependent on partners, especially at the government level, although such operations are planned in existing policy and strategic frameworks. The extractive industry and the hydrocarbon sector (Ambatovy, GRTT, LP) as well as airports have developed contingency plans, which are regularly tested. The private sector has put in place a MOU and a Business Resilience Plan with a view to mitigating the impact of disruptions on the private sector.
P2.5. Design infrastructure to fail safely	Is critical infrastructure designed and operated to fail safely to protect occupants/exposed populations by maintaining critical life support conditions or passive survivability?	Moderate	Moderate	The relocation of Logistique Pétrolière's fuel depot provides the best illustration. Logistique Pétrolière specializes in fuel storage and distribution in Madagascar. According to OMH, the oil depot will be relocated from Alarobia to Bongatsara, on the outskirts of Antananarivo. The new depot has a storage capacity of around 60,000 m³—against 15,472m³ for the current one—and an 8.7-hectare green zone providing a safety perimeter around the depot. As far as the private sector is concerned, critical infrastructure is designed and operated to fail safely
P2.6. Design for multiple scales	Is there sufficient cross-scale redundancy (national/regional/ local) in the infrastructure network to maintain critical services? For example, water-storage tanks at community centers to provide back-up supply in the event of a disruption in the water systems at regional or national level.	High	High	Water supply: the networks are not interconnected. 70% of households rely on delivery by trucks, with wells providing an alternative solution for those who have one. High-rise homes initially used water towers, but had to shift in the end to delivery by trucks.
P2.7. Commit to maintenance	Are maintenance and preventative-maintenance programs effective and adequately funded?	Low	Moderate	Infrastructure maintenance often suffers from inadequate funding. For instance, despite the existence of a road maintenance manual developed by CPGU, road maintenance activities cannot be performed for lack of budget. Nevertheless, road rehabilitation works are performed, although in a poorly integrated manner, in the wake of a disaster. The same applies to other public infrastructures. In contrast, the private sector typically engages in proactive maintenance planning and scheduling.
P2.8. Devise long-term investments	Are investments in infrastructure focused on the long-term with appropriate investment in sustaining resilience over the whole lifecycle of infrastructure components (asset or sub-system)?	Moderate	Moderate	Road construction and water supply projects, especially those funded by major donors like AFD, are subjected to quality control. This is not the case in other projects that are implemented according to the technical standards and monitoring approach recommended by the donor. Conversely, the private sector tends to invest in infrastructure with a long-term perspective, and this is reflected through project implementation.
PRINCIPLE 3: ENVIRONMENTALLY INTEGRATED *INTEGRATE NATURAL ENVIRONMENT IMPLICATIONS INTO INFRASTRUCTURE PLANNING AND MANAGEMENT*				
P3.1. Minimize environmental impact	Are adverse effects of infrastructure projects and operations on the ecosystem minimized? Are there good practices in place for environmental impact assessments and are enforced?	Low	High	The MECIE decree (Mise En Compatibilité des Investissements avec l'Environnement) exists, however, due to cumbersome and costly procedures associated with its implementation, particularly the high assessment fees required upfront for environmental permits, only large companies and the public sector have the capacity for environmental impact assessments. Smaller entities are excluded from compliance, resulting in the non-application of the required assessment. Smaller entities, unable to conduct the assessment, disregard the decree. It should be noted that fees must be paid well in advance of the assessment.

PRINCIPLES / ACTIONS / DESCRIPTIONS		IMPLE-MENTATION STATUS	PRIORITY	ANALYSIS / EVIDENCE
P3.2. Use environmental solutions	Are environmental assets and nature-based solutions that can/ could improve resilience considered as an option and valued accordingly when assessing infrastructure development (e.g., through natural-capital accounting)?	Moderate	Moderate	Many sectors are increasingly adopting nature-based solutions (NbS)for disaster risk management. APIPA, for instance, has already considered implementing green infrastructure, including planting vetiver grass for flood control in canals and dikes. Other sectors, such as public works, engage in mangrove reforestation to mitigate coastal flooding and marine erosion. While the consideration of NbS is growing across various sectors, the challenge remains in effectively applying best practices.
P3.3. Integrate ecosystem information	Is information about ecosystems integrated into decision-making in the planning and design of infrastructure?	Very low	High	More often than not, limited environmental information is available during the planning or implementation stages of infrastructure projects. Environmental information is more readily available at the implementation stage or during field studies. This situation leads sectors to devise adaptive measures to mitigate environmental impacts based on their available resources and capabilities. Indeed, it is crucial to have environmental information well in advance, before the implementation or even the planning stage, as it can significantly reduce unforeseen off-budget costs and allow for better preparation of required technical, human, and financial resources for infrastructure project implementati on.
P3.4. Préserver l'environnement naturel	Are regulations and policies in place for maintaining the surrounding natural environment by infrastructure?	Low	High	While regulations are in place in Madagascar, their ineffective application poses significant challenges. For instance, the National Office for the Environment (ONE) is responsible for approving infrastructure projects based on established categorization. Yet the real concern lies in the monitoring and evaluation of environmental compliance. Environment protection is a critical issue in Madagascar and must be taken into account in any effort to achieve resilient infrastructure.
P3.5. Use local sustainable resources	Is sustainable procurement a standard practice and are locally available resources prioritized where possible?	Very low	High	In many cases, the requirements for infrastructure projects are primarily influenced by donor expectations rather than being tailored to the specific needs of individual sectors. Furthermore, procurement decisions are largely dictated by economic costs, as the benefits of local suppliers are weighed against potentially lower-priced options from outside the project area.
PRINCIPLE 4: SOCIALLY ENGAGED *EMPOWER COMMUNITIES TO PARTICIPATE IN INFRASTRUCTURE RESILIENCE AND DISASTER PREVENTION.*				
P4.1. Inform people about disruptions	Are users of critical services informed about expected or ongoing disruptions so they can proactively adjust their usage?	Low	Moderate	The messages are understood, but are not always adhered to by the community due to insecurity and misperceptions linked to the socio-political situation.
P4.2. Raise resilience literacy	Are education initiatives designed to build awareness around how communities can contribute to infrastructure resilience?	Very low	High	There is a lack of training in infrastructure resilience.
P4.3. Incentivize demand behavior	How effective are incentive programs aimed at reducing demand-based (excessive demand) critical services disruptions?	Very low	Low	Excessive demand stems from overuse and inadequate supply. As it is worded, the question does not apply to Madagascar. The country's weak infrastructure capacity does not allow to meet all needs and demand.

PRINCIPLES / ACTIONS / DESCRIPTIONS		IMPLE-MENTATION STATUS	PRIORITY	ANALYSIS / EVIDENCE
P4.4. Encourage community participation	Are exposed communities appropriately engaged on infrastructure decisions to improve sense of ownership and trust in infrastructure resilience?	Very low	Moderate	Community involvement is very high in rural areas but lower in urban areas.
PRINCIPLE 5: SHARED RESPONSIBILITY *EMPOWER COMMUNITIES TO PARTICIPATE IN INFRASTRUCTURE RESILIENCE AND DISASTER PREVENTION.*				
P5.1. Harmonize open standards	Are harmonized open-data standards that improve overall resilience by enabling collaboration between different stakeholders, including governments, private organizations and the public being used?	Low	Moderate	A few exchange platforms require information sharing from operators in various sectors in times of shock. Maritime sector: Several information-sharing platforms are jointly operated at port level (international committees are monitoring port activities, i.e. port traffic, port safety and security) by port authorities, maritime administration, customs authority and port agents. Mining sector: a robust communication structure exists (information about incidents and disasters is effectively shared with all employees). Private sector: the feedback mechanism is used for communicating information after an investigation, i.e. wide dissemination of lessons learned (e.g. PSHP). Furthermore, a standardized guideline for sharing information is in place. CPGU (cross-sectoral level): Disaster risk information are shared via the DesInventar platform. The CNGRC shares DRR information to all sectors. The BNGRC has put in place an online platform with support from the World Bank-funded Mionjo program. There are also key resource-persons from FID: they rely on compliance with the standards already in use; in the education sector, virtual or face-to-face meetings are organized 2 or 3 times a year to provide feedback and share information.
P5.2. Cultivate collaborative management	Is there open communication within and between sectors on resilience activities that provide opportunities for learning and improvement in infrastructure resilience?	High	Low	Collaborative management exists among sectors: general meetings take place twice a year whereas the six thematic groups meet three times a year.
P5.3. Establish shared responsibilities	Is there clear accountability and understanding of roles and responsibilities for relevant stakeholders in responding to threats, hazards and/or failure events?	High	Low	At the regional level, contingency plans establishing channels for flow of information are available. There is also mandatory reporting by the private sector on progress in risk management as well as in crisis anticipation, preparedness and response. Additionally, Specific Response Plans which clearly delineate the roles performed by various community entities should the risks occur have been developed, demonstrating close collaboration between the Government and the private sector. The private sector has defined specific standards of operations, with responsibility matrix as regards the collaboration with authorities. Financing of intervention capacities by the private sector.
P5.4. Enhance connectivity for information sharing	Is data being shared between the sectors, sector infrastructure and relevant organizations?	Low	Moderate	Data sharing remains fairly limited due to the sensitive nature of the information, leading to strict governance through charters and non-disclosure agreements.

PRINCIPLES / ACTIONS / DESCRIPTIONS		IMPLE-MENTATION STATUS	PRIORITY	ANALYSIS / EVIDENCE
P5.5. Assure data safety to develop trust	Are there robust data-sharing security practices and programs in place?	High	Low	In the private sector, a systematic protocol for analyzing and approving information prior to sharing should be generally followed to avoid exposure, while remaining within a legal framework. At the national level, INSTAT has the exclusive authority to publish data—submitted by ministries for unification by INSTAT. Otherwise, data sharing will be on a case-by-case basis depending on the sensitivity of the data (e.g. non-disclosure of information in surveys for INSTAT).
P5.6. Share risk and return information	Is infrastructure risk information publicly available where appropriate to promote risk-informed investment?	Moderate	Moderate	In the private sector, transparency is pivotal when it comes to sharing information. This is the case with Environmental Social Governance (ESG) reports, which donors often mandate for public release to showcase social and environmental outcomes. In the mining sector, a committee has been set up to conduct on-site inspections of mining activities and engage workers' committees to gather feedback and ensure ongoing oversight. At the national level, a risk atlas for the African region has been developed in collaboration with the World Bank and is available with CPGU. However, sectoral data input is almost non-existent.
PRINCIPLE 6: ADAPTIVELY TRANSFORMING *CRITICAL ASSETS ARE DESIGNED TO OPERATE COMFORTABLY IN HAZARDOUS CONDITIONS AND DURING EXTREME DISRUPTION EVENTS*				
P6.1. Choose manageable solutions	Are infrastructure solutions in terms of complexity and modularity considered and aligned to the skills and resources available in local environments where possible?	Very low	High	There are usually no accessible emergency solutions within a day's drive of the affected site. Generally, when it comes to infrastructure, emergency solutions do exist, but the quantity available is limited. In the energy sector, outdated machinery and equipment pose serious challenges. The unavailability of suitable spare parts necessitates adaptation of existing parts, otherwise repair is delayed as it takes days to find the right part. Yet it is crucial that machinery and equipment continue operating effectively in the face of hazards.
P6.2. Create adaptive capacity	Is adaptive capacity built into infrastructure systems at all lifecycle stages to allow flexibility in decision making and problem solving?	High	Moderate	Preparedness is effective across sectors to mitigate the possible impacts of disasters and appropriate measures are in place. By way of example, the Ministry of Telecommunications has established a government-supported data center where data from various ministries are stored and can be retrieved when required. Another example is the CPGU's existing continuity plan for essential services in the event of a disaster. If a cyclone hits, for instance, its path and the areas that may be affected are known in advance. Therefore, pre-emptive measures are taken, such as deploying spare resources, including bailey bridges and human and material resources, to district capitals ahead of time to ensure continuation of essential services post-disaster.

PRINCIPLES / ACTIONS / DESCRIPTIONS		IMPLE-MENTATION STATUS	PRIORITY	ANALYSIS / EVIDENCE
P6.3. Develop flexible management	Is there a culture of dynamic management within infrastructure operators where there are feedback loops between management, staff and community that facilitates and improves effectiveness of disaster response?	High	Moderate	The infrastructure affected are generally for public use and built by the Government. Therefore, information feedback exists through coordinated efforts managed by the BNGRC, which houses the Centre d'Études, de Réflexion, de Veille et d'Orientation (CERVO). Disaster information-sharing is facilitated at the level of governmental subdivisions via dedicated committees, including local DRM committees (Comité Local de GRC CLGRC) at fokontany level, commune DRM committees (Comité Communal de GRC, CCGRC) at commune level, district DRM committee (Comité de District de GRC, CDGRC) at district level), and regional DRM committees (Comité Régional de GRC (CRGRC) at the Region's level. Additionally, the Disaster Response Advisory Committee (Comité de Réflexion des Intervenants en Catastrophe, CRIC) plays an active role in enhancing disaster warning and management protocols.
P6.4. Enable capacity for transformation	Is there planned and deliberate capacity in critical infrastructure assets to adapt beyond primary purposes to provide overlapping redundancy and ability to redistribute stress?	Low	High	In the event of risks materializing, Madagascar has a contingency plan in place, which includes redundancies for essential services. However, the main challenge remains in the effective implementation of this plan. Most stakeholders resort to "system D", relying on improvised solutions that are within their reach.
P6.5. Allow for human discretion	Is there sufficient and appropriate provisions for human discretion and intervention in standard operating practices for flexibility in unexpected situations?	n/a	High	There is no emergency training or drills at community level. Only those in charge or DRM specialists are trained to operate equipment effectively. Although information and instructions are available through various transmission channels, there is a lack of specialized emergency training.

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