HIGH VOLUME TRANSPORT
APPLIED RESEARCH

CLIMATE-RESILIENT TRANSPORT

A policy guide

UNIVERSITY OF BIRMINGHAM | BCRRE

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STATEMENT

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FOREWORD

Transport infrastructure is integral to the development of society. Investment in transport infrastructure and its maintenance lowers transport costs, reducing the associated costs of goods and services, thus promoting economic growth, employment and profitability.

Such investments not only ease mobility and create employment but also have related benefits. These include the quality of the environment we live in, improvements in social-cohesion, economic growth and alleviation of poverty. However, a distinction should be made between the quality of and access to transport infrastructure in urban and rural areas, including the degree of equity between these locations.

Transport infrastructure is vulnerable to the impacts of extreme weather events and climate change. Flooding can wash out roads and bridges, cutting off supply chains; storms can disrupt transport services, disconnecting communities from essential services; and heatwaves can buckle railway lines, preventing trains from running. Therefore, transport infrastructure should be resilient to limit the social and economic consequences of transport services not operating.

Low-income countries and their transport infrastructure are particularly vulnerable. Climate change awareness is growing but is still in its infancy. It is encouraging to note that the realisation by governments of the need to address aspects relating to climate change has increased, often because they have experienced the impacts of a very severe weather event.

Although the climate change emergency is a global issue, the impacts are often local. Each event presents different challenges. Therefore, a multi-dimensional and interdisciplinary approach to future-proofing transport infrastructure is required. Everyone needs to come together, take ownership of the transport infrastructure they depend on and play a part in making it more resilient. Furthermore, the role of social networks and their adaptive capacities are important sources of resilience within communities.

The COP26 summit held recently in Glasgow, United Kingdom, made it very clear that action is urgent. Commitments to increased finance packages specifically for adaptation to support low-income countries' plans will help. However, the increased finances are arguably insufficient. It also requires a change in behaviour by society at large.

There are many ways that transport resilience can be improved through adaptation actions. This policy guide sets out how to approach adaptation for transport resilience, with a focus on low-income countries. It brings together key information and resources needed for each step of the process through a framework approach that will support strategic planning and action – which is critical for safe and reliable transport networks for future generations.

This guide for policy makers is based on thorough research and expert support and is a tool for countries to utilise when assessing their transport infrastructure and planning for its future. I also hope that it is useful when planning support for low-income countries. Now is the time to act to make transport infrastructure resilient in the face of climate change.

At PIARC, we identified that resilience and climate change are major issues facing the road sector and are addressing them as cross-cutting issues in our current Strategic Plan (2020-2023). We have constituted a Technical Committee with our international experts to identify and share best practices. I am glad that its Chair was a member of this project's advisory group. This Committee is tasked with analysing methodological approaches to climate change, resilience and other hazards including updating the PIARC International Climate Change Adaptation Framework for Road Infrastructure (published in 2015). With this in mind, our 16th World Winter Service and Road Resilience Congress, organised with Transport Canada and the City of Calgary in February 2022, was dedicated to finding answers to the various related issues.

Thank you and congratulations to the project team and FCDO on an excellent and timely initiative. PIARC looks forward to its continued partnership with the FCDO, which has a decades-long history in producing relevant documents sharing experiences and events related to transport infrastructure.

Nazir Alli
President of PIARC

INTRODUCTION

The climate is changing. Mean global surface temperature has increased since industrialisation because more greenhouse gases, such as carbon dioxide, have been released into the atmosphere as a consequence of meeting the needs of modern life. Shifts in Earth's climate are leading to changes in temperature and precipitation, and a rise in sea levels. Extreme weather events are changing in frequency and magnitude, which can result in major damage to infrastructure that people depend on to access education, healthcare, employment and more. Even with global efforts to reduce greenhouse gas emissions, the world is already experiencing an increase in climate-related hazards, particularly in the last decade.

Resilient transport networks that can withstand the impacts of weather and climate change are crucial in order to sustain the social and economic needs of communities. This is a particular challenge for developing countries, as losing a vital – or in some cases the only – transport link to essential services can exacerbate existing risks or introduce new risks associated with poverty. Moreover, low-income countries (countries with the lowest gross national income) are located in regions of the world that are already experiencing the greatest impacts of climate change, such as drought, extreme heat and storms with heavy rainfall and associated flooding.

Addressing the challenges that transport networks face in low-income countries due to climate change supports the United Nations Sustainable Development Goals (SDGs) for 2030 in both direct ways, such as making cities and human settlements inclusive, safe, resilient and sustainable, and indirect ways – for example by reducing poverty and hunger, improving access to quality education, providing decent work opportunities and fostering economic growth. This emphasises the importance of taking steps to improve transport resilience.

This policy guide provides background and context on the problem and practical steps to develop, prepare and implement adaptation plans for transport resilience to climate change. Its information is based on findings in a recent State of Knowledge report on Adaptation for Transport Resilience in Low-Income Countries in Africa and South Asia, and as such, it is targeted at policymakers in these regions. Nevertheless, this guidance should be useful for all those involved in transport resilience.

The need to make transport networks more resilient is urgent – and is possible to do so by acting now. It begins with raising awareness and engaging fully with stakeholders on the issues, with firm commitments on action from government. Adaptation plans and strategies with strong foundations and based on good data should enable robust monitoring and evaluation processes, which in turn will support continuous investment and improvement in resilience. There is a wide range of tools and resources available to support adaptation planning for transport resilience and many of these are referred to in this policy guide.

One of the outcomes of COP26 was the Glasgow Climate Pact, which urges Parties to communicate and continue to review their pledges in reducing emissions and taking action to adapt to climate change in the format of a nationally determined contribution, or NDC. An NDC is a key document that provides a foundation for national adaptation planning. However, to date, neither NDCs or national adaptation plans typically include much detail on the transport sector, despite its essential role for nations, societies and individuals.

Commitments from all those engaged in and affected by transport matters – from policymakers and transport authorities to businesses and civil society – can and should make a difference in developing more resilient transport networks for the benefit of their users.

Urgent action to adapt is needed

Climate change and extreme weather events are linked. As the mean global surface temperature rises, so have the instances of weather-related disasters around the world. Since the turn of the century, the number of reported events has grown sharply.

Extreme weather events are a humanitarian risk. Hundreds of thousands of people can lose their lives and nations and businesses together may lose billions (in US dollars) due to a single event. Low-income countries in Africa and Asia have experienced particularly rapid growth in the number of flooding and storm-related disasters.

These extreme weather events have been increasing since pre-industrial times and their frequency and intensity will escalate in future. Urgent action is necessary through adapting infrastructure and building resilience to reduce the impacts of these events – even if future warming is limited.

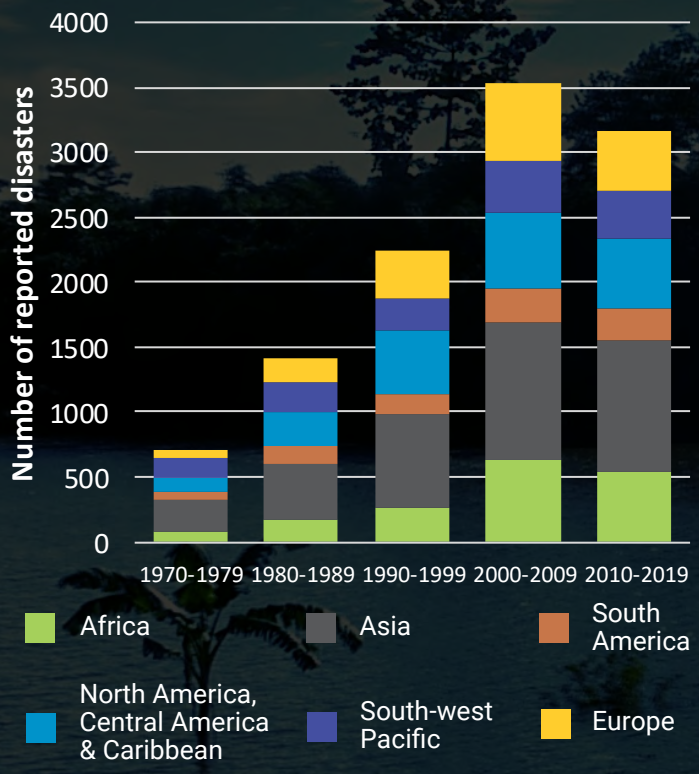


Figure 1: Total number of reported weather-related disasters by regions, 1970-2019[1]

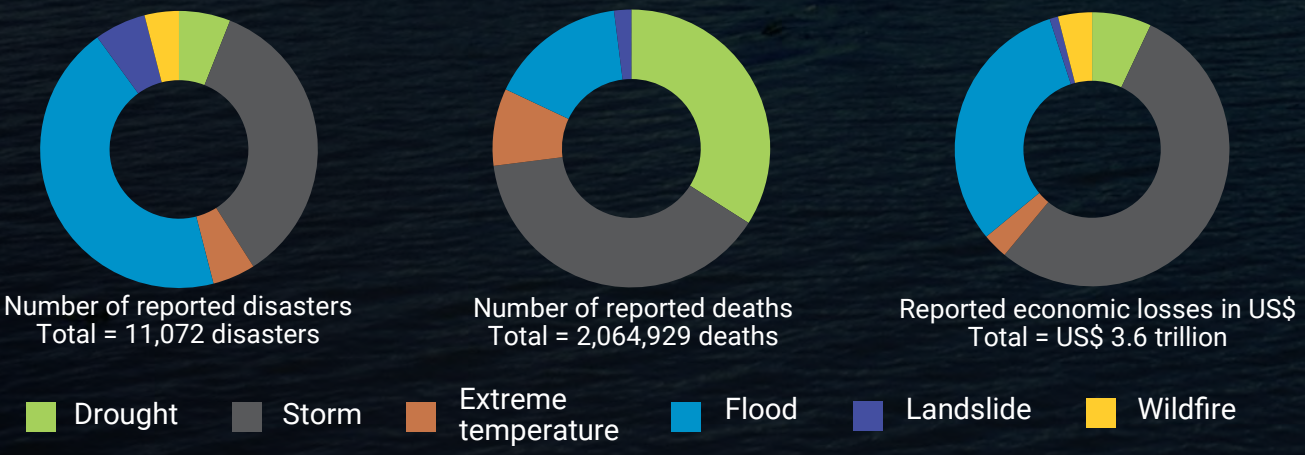


Figure 2: Global distribution of weather-related disaster statistics by type of disaster, 1970-2019[1]

Image: Pradip Nemane

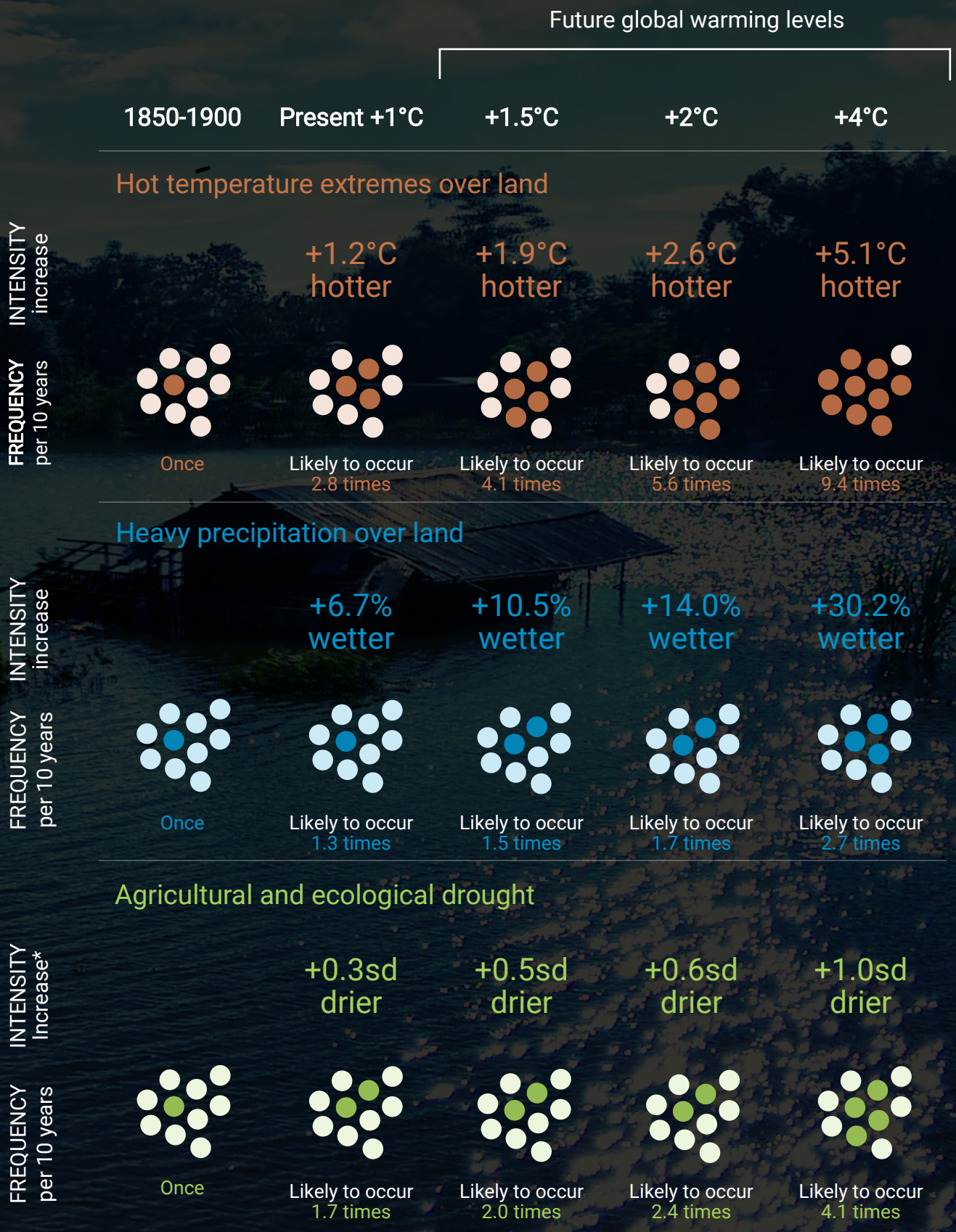


Figure 3: Projections of frequency and intensity of hot temperatures, heavy precipitation and drought[2]
* sd = standard deviations of the interannual variability, 1850-1900

Transport resilience in low-income countries

Low-income countries are highly vulnerable to climate change and do not have the capacity to withstand and adapt to its impacts. Because of this, their transport networks are unlikely to be resilient.

Resilience, according to the Intergovernmental Panel on Climate Change (IPCC) is defined as:

"The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation."[3]

In this context, a resilient transport network is one that is able to cope, respond or react in such a way that it retains its essential function. Making transport climate resilient requires adaptation, which is the process of adjustment to actual or expected climate and its effects in order to moderate or avoid harm or exploit beneficial opportunities.

Resilience can be physical and/or operational. Improving the physical resilience of a transport network may include "hard infrastructure" measures, such as improving flood defences or increasing drainage capacity. Operational resilience may involve "softer" approaches, such as adjusting timetables, improving staff availability and revising maintenance schedules. It should also include nature-based solutions that address both the resilience issue and improve the natural environment by protecting, sustainably managing and restoring natural or modified ecosystems.

There is no single or universal approach to improving transport resilience and adaptation, because the environment, situation and capabilities of transport infrastructure and operators vary. It therefore requires careful assessment to ensure the right approach is taken.

THE CLIMATE EMERGENCY

The world is facing a climate emergency and the consensus is that climate action should not only do everything necessary to address this but also do it urgently[3].

In 2021 alone, there were record-breaking heatwaves in North America and southern Europe, forcing people into their cars and increasing use of air conditioning. In British Columbia, Canada, the heatwave melted mountaintop snow, inundating roads and submerging vehicles. Wildfires in California, Australia, Turkey and Greece engulfed highways and feeder roads, trapping people in their homes and blocking rescue vehicles. Fierce storms also hit Europe throughout July, causing flash flooding that disrupted transport routes and stranded vehicles.

The climate is changing in different ways in different parts of the world, which means that the impacts of climate change vary from place to place. What is important to recognise is that **climate change is already happening** and its impact on transport infrastructure may worsen over time if no action is taken.

Weather and climate change cause damage to transport infrastructure, which disrupts networks in two primary ways. Firstly, sudden shocks to infrastructure from a single extreme event, such as a cyclone, can cause extensive damage that may necessitate intensive repairs. Secondly, gradual changes over time in weather variables, such as temperature and precipitation, can slowly accelerate the deterioration of transport assets, requiring increased levels of maintenance.

Table 1: Approaches to increasing transport resilience[4]

Approach	Description
Anticipate	Actions to prepare in advance to respond to shocks and stresses.
Resist	Actions taken in advance to help withstand or endure shocks and stresses.
Absorb	Actions that, accepting that there will be/has been an impact on transport, aim to lessen
Recover	Actions that help restore expected service levels quickly.
Adapt	Actions that modify the system to enable it to continue to deliver services in the face of
Transform	Actions that regenerate and improve infrastructure systems.

How the climate is changing in Africa and South Asia

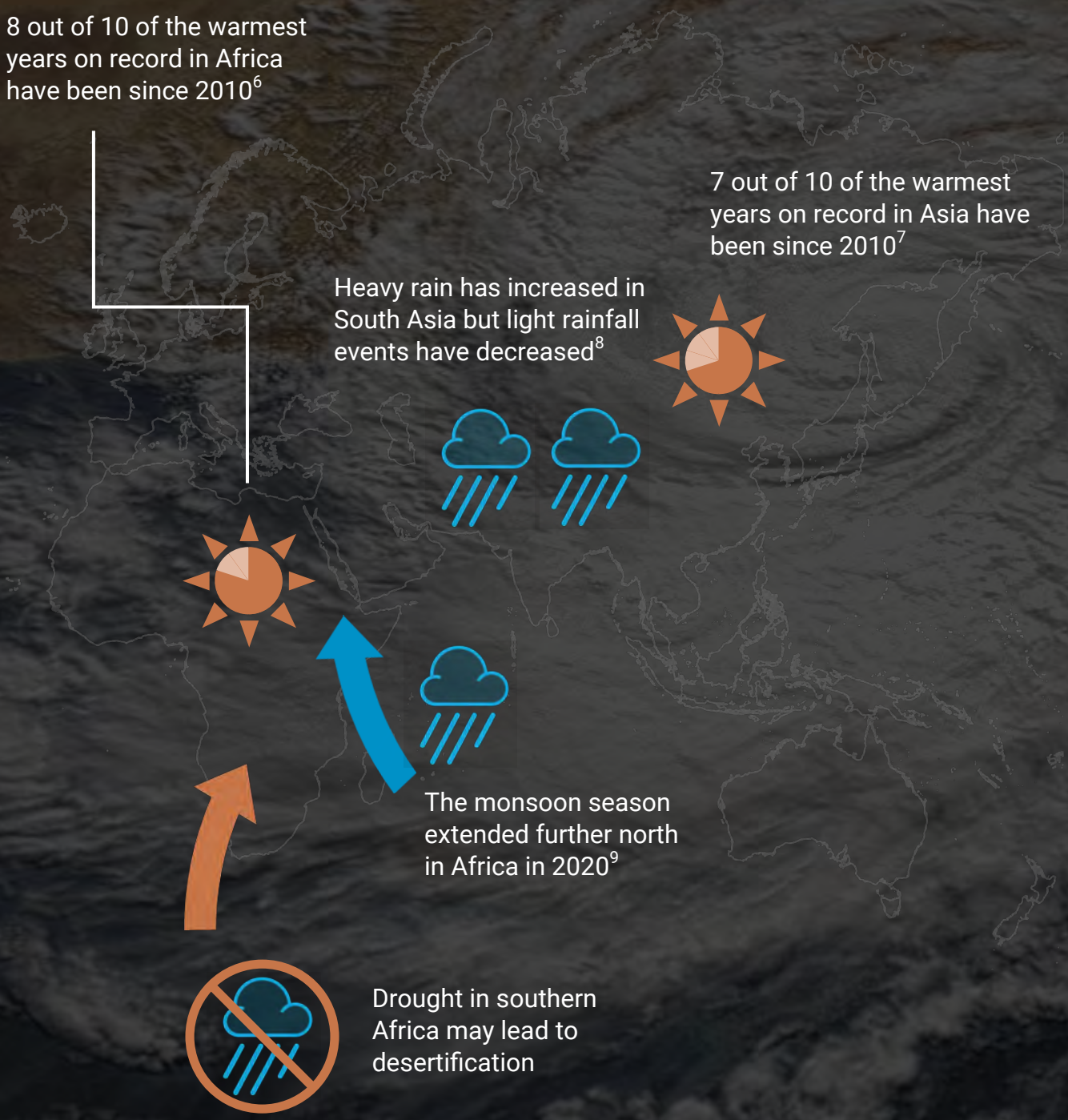


Image: Antti Lipponen

REASONS FOR LOW RESILIENCE

The low levels of resilience to the impacts of weather and climate change in some transport networks are often due to factors associated with **gaps in knowledge, resources and money**, which all lead to capacity issues. Interviews with transport stakeholders in low- and lower-middle-income countries in Africa and South Asia suggest there is little awareness of the impacts of climate on transport networks and that measures in place to manage assets and infrastructure, such as design standards or maintenance schedules, rarely take account of weather or change in climate.

Transport as a sector is not always prioritised for climate change adaptation in low-income countries, for example in national adaptation plans. Therefore, compared with other sectors, it does not get the attention required to improve resilience.

Collecting and analysing data on how weather affects infrastructure assets is essential in order to improve transport resilience. Without it, there is no robust evidence to support decision-making, prioritise actions or plan effectively.

The types of data required include weather observations, transport asset vulnerability and exposure data, and climate projections. In low-income countries, such data may be patchy or missing altogether. What is available can be difficult to access, inadequate or not at the appropriate scale for transport stakeholders to analyse sufficiently. It may also come at a cost, or those who collect or hold it are not willing to exchange it for free.

Funding is crucial in planning and delivering resilient transport networks. Transport infrastructure practitioners report a low awareness of ways to increase or diversify income, or how to approach funders. Without the right level of funds, it is not possible to improve the resilience of transport infrastructure.

LOW TRANSPORT RESILIENCE HAS SOCIAL AND ECONOMIC IMPACTS

Transport is essential to move resources and produce and access essential services. Any disruption to transport caused by an extreme weather event could have severe consequences.

A lack of adaptation planning may result in economic loss in terms of gross domestic product (GDP). Predictions for Ethiopia[8], for example, are:

- In a drier future climate, losses will consistently be 6% to 10% of GDP between 2010 and 2050;
- In a wetter future climate, GDP losses will be greater after 2030 because of the costs of coping with climate change.

Disruptions to transport services also have an impact on public health infrastructure and services. They therefore have a knock-on effect for people who need to access health services and on emergency services callouts.

For children, transport disruption can impact school attendance and education. Roads greatly influence where schools are built[11], with poor and rural communities likely to be more adversely affected than others because their transport services are already limited.

WOMEN ARE DISPROPORTIONATELY AFFECTED

Climate change is unlikely to affect all communities or demographics equally. Women may face specific challenges due to weather- and climate-related transport disruption. When women's access to transport is compromised, it impacts access to resources such as food and medicine. Involving more women in decision-making within transport authorities would help to address these issues.

Women's travel patterns often differ to those of men:

Work and familial duties differ, such as maintaining household food security and caring for sick or elderly relatives[12].

Women are more likely to work from, or closer to, home and have more complex journey patterns due to taking children to school, shopping and/or visiting clinics[11].

CLIMATE CHANGE IMPACTS ARE LIKELY TO WORSEN

For Africa and Asia, even if future mean global surface temperature increases are limited[2], the projected changes in climate of most concern relate to changes in precipitation, including:

- Shifts and extensions in monsoon seasons;
- Increased rainfall from landfall cyclones;
- Prolonged drought events;
- More unpredictable extreme rainfall.

IMPACTS OF WEATHER AND CLIMATE CHANGE ON TRANSPORT

Weather and climate change impacts transport primarily through damage to infrastructure. The type and extent of damage depends on the climate hazard or weather type, as well as the transport mode. In some cases, multiple modes of transport are affected.

The impacts of flood-related damage are easy to identify and measure. Heat-related damage can be more challenging to measure, but the impacts can be more widespread.

In the context of transport, flooding and precipitation is problematic for roads because it has a direct link with traffic safety, as it increases the likelihood of more frequent accidents[13]. Heat also is a major risk to rail infrastructure, because if temperatures exceed maximum design thresholds on railway tracks, rails may expand and "buckle", increasing the risk of train derailment.

There are different ways in which costs may be incurred due to weather and climate impacts on transport infrastructure:

Repair and maintenance: Repair costs may increase as the frequency and intensity of extreme weather events increase, because there is more damage. Gradual changes in climate may accelerate the aging of assets, which may increase maintenance needs.

Infrastructure modification: Major replacement works may be necessary to increase the resilience of transport, for example to withstand higher temperatures or more extreme precipitation and flooding.

Operational change: Transport may need to be adapted to meet the comfort requirements of passengers and workers and the conditions needed for transporting perishable goods, such as increased air conditioning, which would result in increased energy use.

Table 2: Examples of climate events and the impacts on transport infrastructure

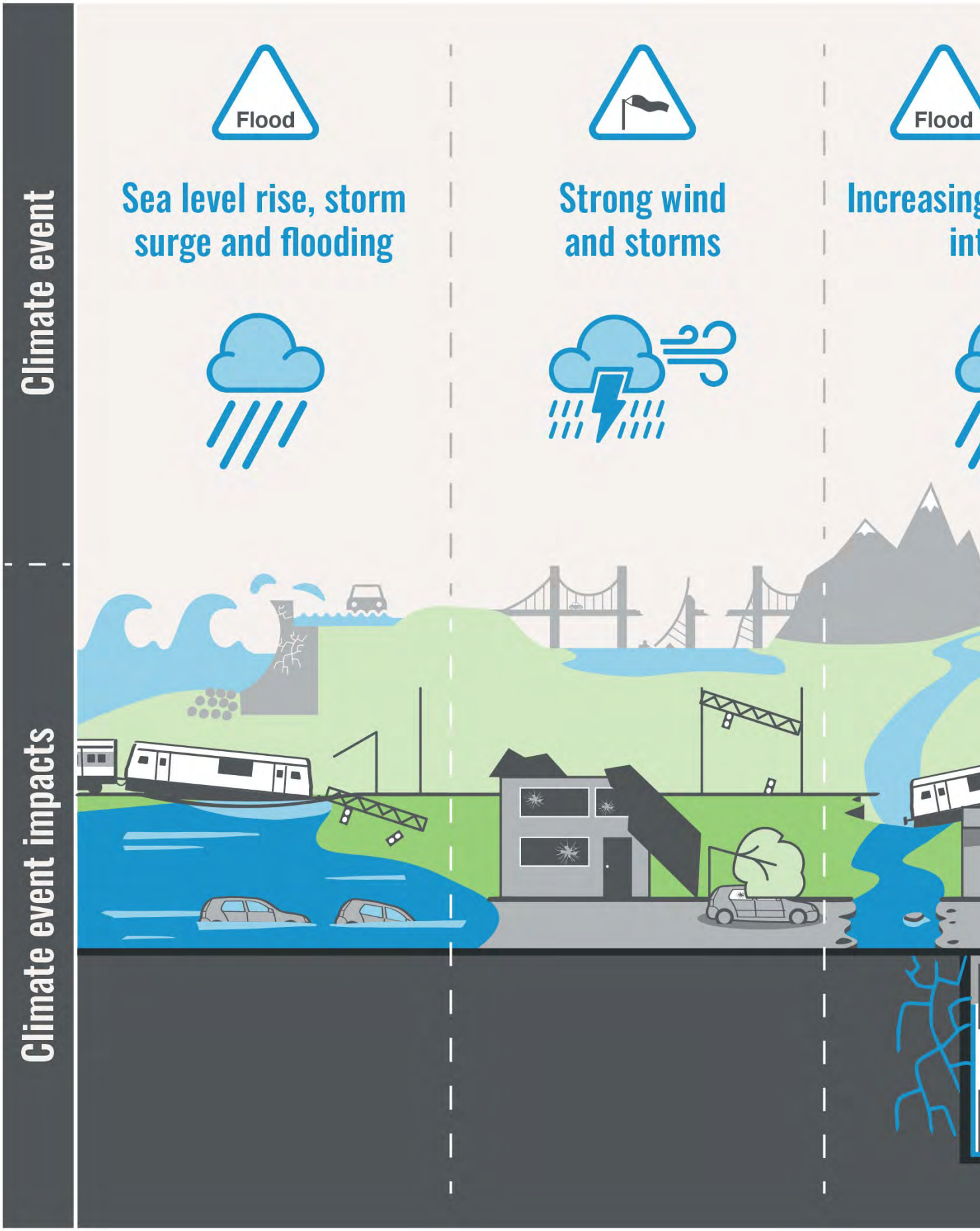
Climate event	Climate event impacts
Sea level rise, storm surge and flooding	Damage to, or inaccessibility of, low-lying coastal infrastructure; port infrastructure damage and disruption to shipping traffic; damage to coastal defences; aggravated coastal flooding; increased dredging requirements.
Strong wind and storms	Higher chances of infrastructure failure and disruption to operations; damage to overhead lines for railways for power supplies, signs and lighting; increased tree fall that may close roads and railways; flight cancellations and delays; poor visibility.
Increasing precipitation intensity	Flooding of roads, railways and tunnels; slope failures and landslides; washout of gravel and earth roads and railway tracks; erosion and scouring or washout of bridges; poor visibility; increased sediment loading of drainage works.
Change in mean precipitation	Increased drought, reducing the navigability of inland waterways; increases or decreases of soil moisture levels affecting road structural integrity; subsidence of infrastructure and road beds from increased aridity; damage to roads from
Extreme heat	Increased pavement deterioration; rail track deformation and buckling; reduced asset lifetime; shorter maintenance windows; thermal expansion of bridge joints; increased chance of wildfires; decreased airport runway traction.

“Although climate change is a global phenomenon, its impacts are felt at the regional and local levels, and it is at these levels where actions to adapt to it and mitigate its effects are required.”[14]

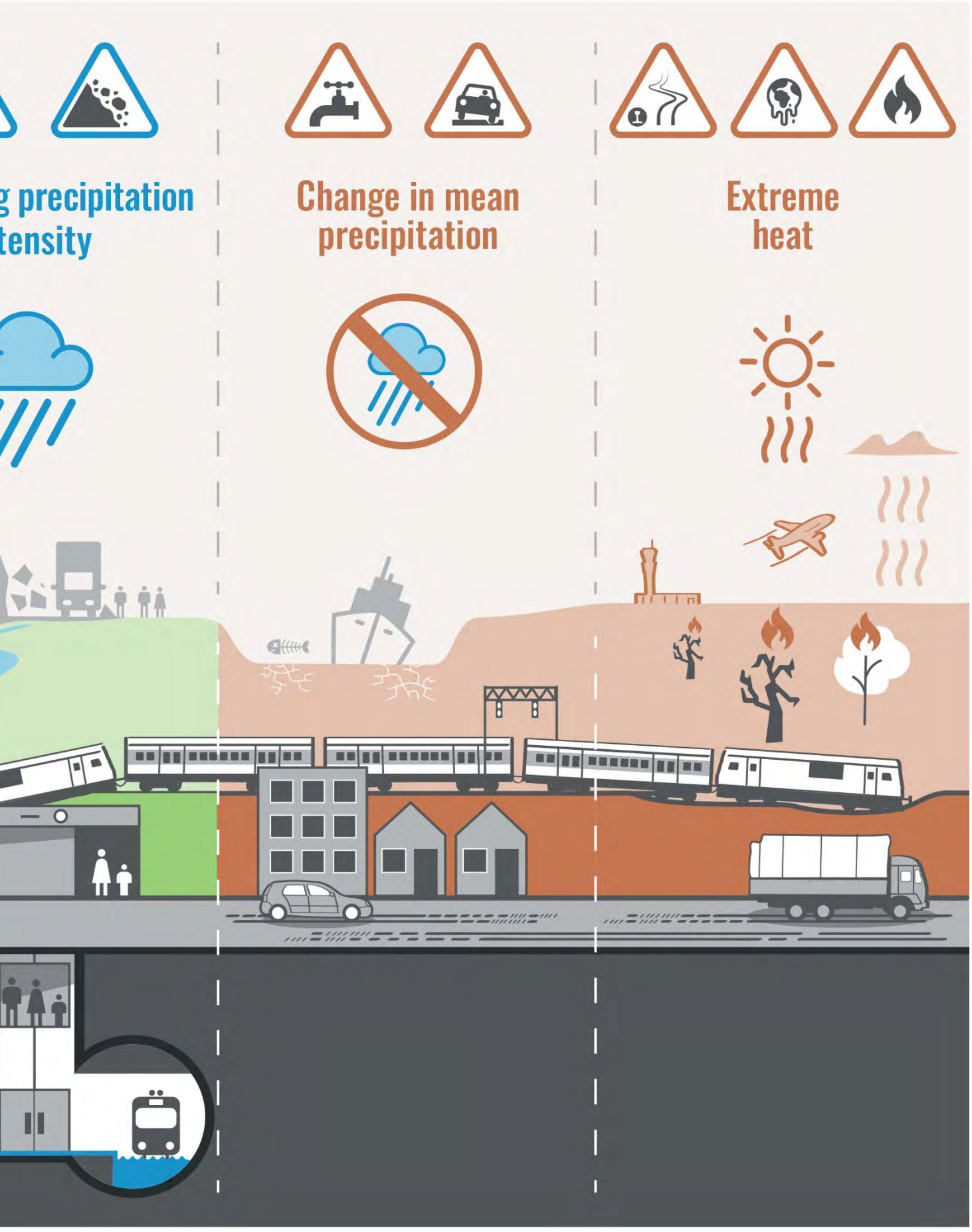
Petteri Taalas, Secretary General, World Meteorological Organization, 2019

Image: Carsten ten Brink

Impacts of Weather & Climate Cha



nge on Transport Infrastructure



Delivering Climate-Resilient Transport Supports SDG 13 Climate Action and other SDGs

Information obtained from the SDG Climate Action Nexus tool (SCAN-tool) for adaptation[15].

MORE INDIRECT TARGETS:

4.3 Affordable access to technical, vocational and tertiary education

4.4 Increase youth and adult employment skills

4.5 Eliminate gender disparity in education

4.6 Increased adult numeracy and literacy

4.A Upgrade education facilities for inclusive learning

BENEFITS OF IMPROVING RESILIENCE

A transport network that is resilient to the impacts of weather and climate change ensures that the system can continue its essential service to modern society, enabling daily life to continue. Delaying adaptation planning for infrastructure resilience is likely to result in increased costs to deal with the impacts in the future, so action now is desirable.

More resilient transport systems can support low-income countries in driving down poverty. Poorer populations are more likely to be dependent on public transport for access to education, jobs, markets and services. Additionally, as rain-fed agriculture makes up a major part of low-income country economies, any disruption in the supply chain has an impact on food security. It is therefore critical to ensure networks remain operational all year round.

With resilient transport systems in the right place, access to local and international markets can improve. This is likely to boost the competitiveness of products in regional and international markets[16].

The Global Commission on Adaptation[17] identified multiple benefits of adaptation, known as the "triple dividend":

Avoided losses: The ability of the investment to reduce future losses.

Economic benefits: Through reducing risk, increasing productivity and driving innovation.

Social and environmental benefits: Harder to quantify, but include non-market benefits such as habitat protection through nature-based adaptation solutions.

MEETING THE SDGs

Successful implementation of resilient transport systems can help with meeting the SDG targets. Overall, such actions support SDG 13 on climate action[18]. More specifically, according to the SCAN-tool for adaptation[15], seven of the 17 SDGs have positive links between transport adaptation and achieving SDG targets, as illustrated on page 16. Policies that reduce vulnerability or exposure help form the positive links between transport adaptation and SDGs. SDG targets are either affected directly or indirectly from such policies.

Directly meeting SDG targets

Improving transport resilience through policy directly and positively links to four SDG targets:

- 3.6: Halve the number of global deaths and injuries from road traffic accidents;
- 9.1: Develop quality, reliable, sustainable and resilient infrastructure;
- 11.2: Provide access to safe, affordable, accessible and sustainable transport systems for all;
- 11.6: Reduce the adverse per capita environmental impact of cities.

Indirectly meeting SDG targets

Indirect links between transport resilience and SDGs are mainly socio-economic. Resilient transport enables continued connectivity of people to goods and services. Therefore, emergency services are not disrupted, businesses can keep operating, children can still attend school and rural or remote communities can still access essential supplies.

COVID-19: BUILDING BACK BETTER

The COVID-19 pandemic has had devastating impacts globally. Countries closed their borders and enforced social distancing measures, both of which affected the transport sector because a large proportion of non-essential traffic effectively ground to a halt in an effort to reduce the spread of the virus. Global supply chains were disrupted, leading to shortages of essential supplies such as food and medicine[19].

There are parallels between the climate emergency and the COVID-19 pandemic, particularly regarding effective response in the face of a crisis, including the ability to react quickly and work collaboratively to protect people, while at the same time ensuring essential needs are met. Transport policy plays a crucial role in facilitating such responses.

Steps to improve transport resilience

WHY TAKE ACTION?

Transport services are the backbone of society. Virtually everything and everyone has some dependency on transport in some way. Taking action to improve transport resilience will protect lives, livelihoods and economies, now and in the future.

We need to take climate action – that message is clear. Almost every country has ratified the Paris Agreement[20], and governments' focus on adaptation through their nationally determined contributions continues to grow.

The need for adaptation is growing more urgent in developing countries because they are more exposed and vulnerable to the impacts of climate change. National adaptation plans are being developed in many of these countries. The transport sector needs strong representation within these adaptation plans in order to increase its resilience to climate change.

A FRAMEWORK TO IMPROVE TRANSPORT RESILIENCE

This policy guide provides a framework to help policymakers through the necessary processes to increase transport resilience to climate change through adaptation planning. Underpinning the entire framework are three key actions that highlight the barriers to increasing transport resilience:

- Improving coordination between national and local government bodies, and among ministries and sectors;
- Building capacity around climate knowledge and finance;
- Increasing levels of stakeholder engagement at all parts of the adaptation planning process.

There are four key barriers to achieving transport resilience[21]:

Lack of knowledge: Being unfamiliar with or unable to understand the scale of the problem.

Lack of options: Inadequate/insufficient information on appropriate adaptation measures.

Failure to act: Unable to put appropriate measures in place or to address the problem.

Insufficient funds: Not appreciating the scale of the problem or unable to secure funding.

"We must scale up the development and implementation of comprehensive National Adaptation Plans to significantly advance adaptation and resilience-building."[22]

Patricia Espinosa, Executive Secretary, United Nations Framework Convention on Climate Change, 2020

Image: Richard Stupart

“Government officials and business leaders need to radically rethink how they make decisions. We need a revolution in understanding, planning and finance that makes climate risks visible, incorporates these risks into all decisions, and releases public and private financial flows.”[17]

Ban Ki-Moon, Secretary General, United Nations, 2019
Bill Gates, Co-chair, Bill & Melinda Gates Foundation, 2019
Kristalina Georgieva, CEO, World Bank, 2019

Image: oledoe

DEVELOPING A PLAN OR STRATEGY TO IMPROVE TRANSPORT RESILIENCE

The processes in the framework outlined in this policy guide can be used to develop a plan or strategy that captures the challenges, actions and opportunities involved in improving transport resilience.

The documentation that captures the strategy or plan for improving transport resilience can take many forms. The outcomes can be part of a broader plan, such as a national adaptation plan or infrastructure resilience strategy. Documentation can also be a standalone plan, but it is important to ensure it does not undermine or contradict other plans.

EVERYONE PLAYS A PART

When transport is disrupted, the impacts can cut across sectors and impact large parts of society. Therefore, the strategy or plan requires input from multiple stakeholders across society, who need to work together to achieve positive results.

Engaging with a wide range of stakeholders can enhance skills and resources, and support solutions on adaptation and transport resilience in the public sector. It also helps stakeholders take ownership of the climate change challenge.

The icons shown below for each stakeholder are used throughout this policy guide to identify where and how they should contribute. This is not a definitive list, and more stakeholders should be encouraged to participate where they may offer further insights or knowledge.


Environment ministry


Transport ministry


Finance ministry


Communications ministry


National government/Head of state


Emergency services


Disaster risk reduction authority


Road authority


Local government


Meteorological agency


National statistics office

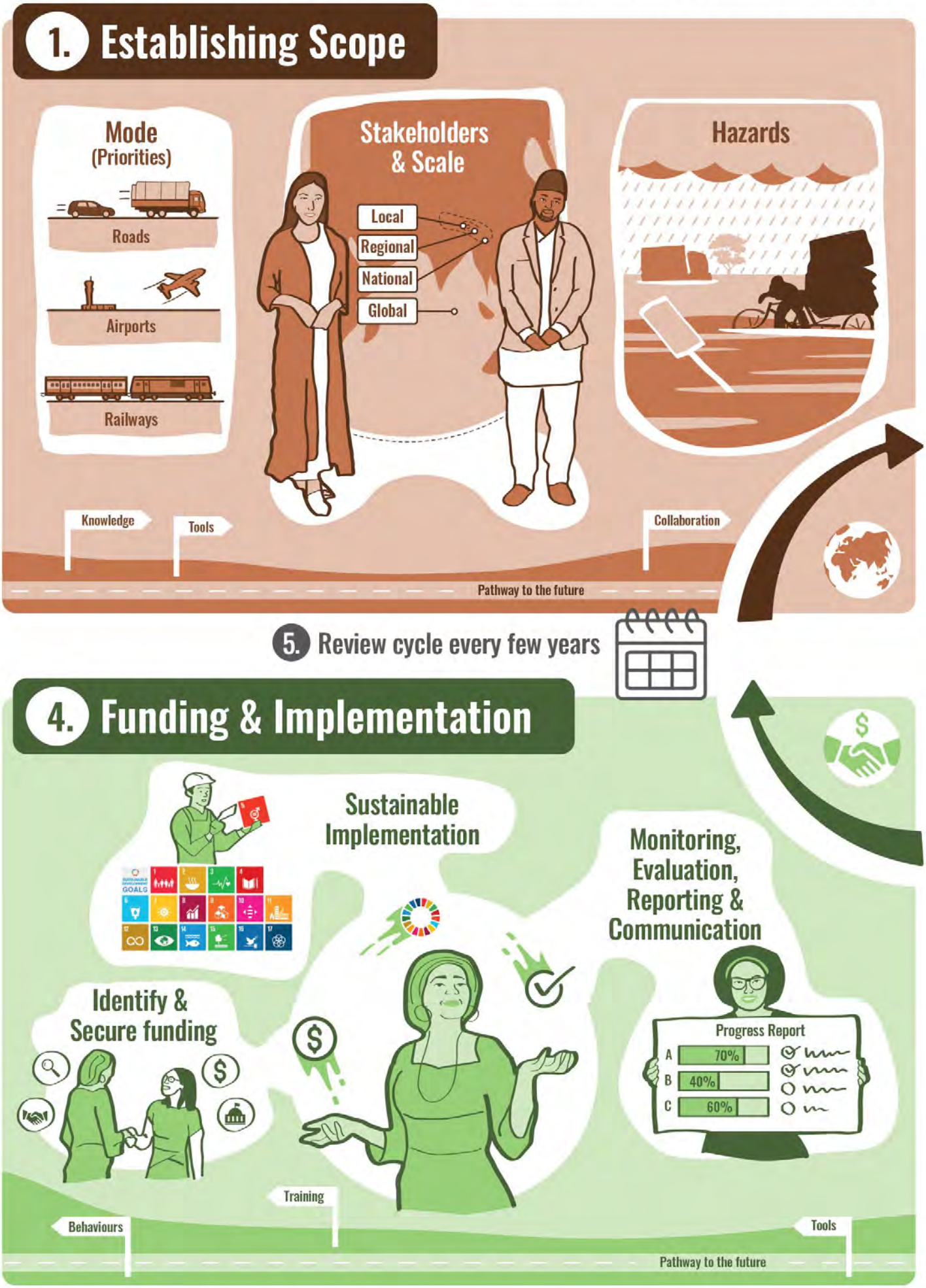

Transport operators

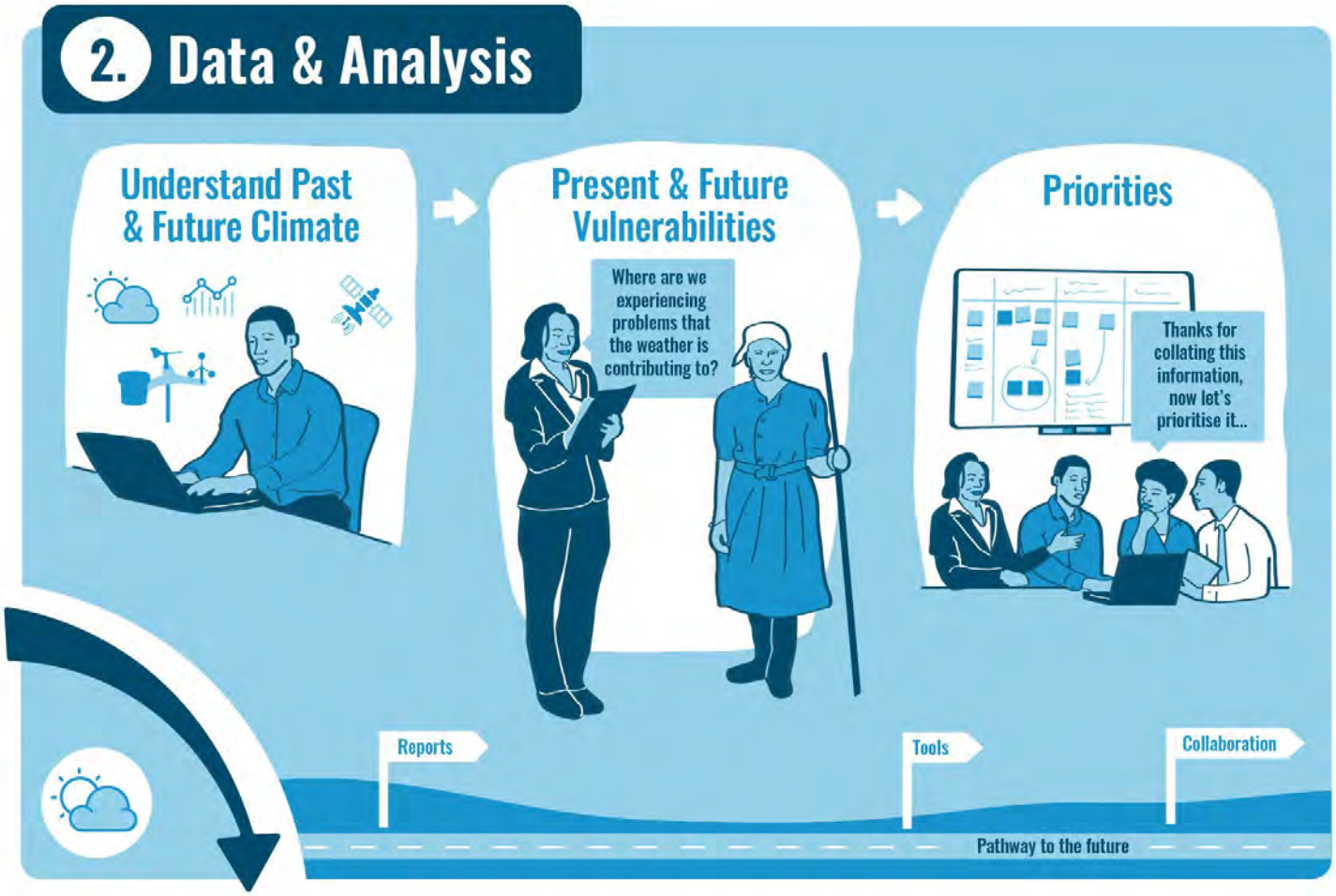

Universities and research institutions

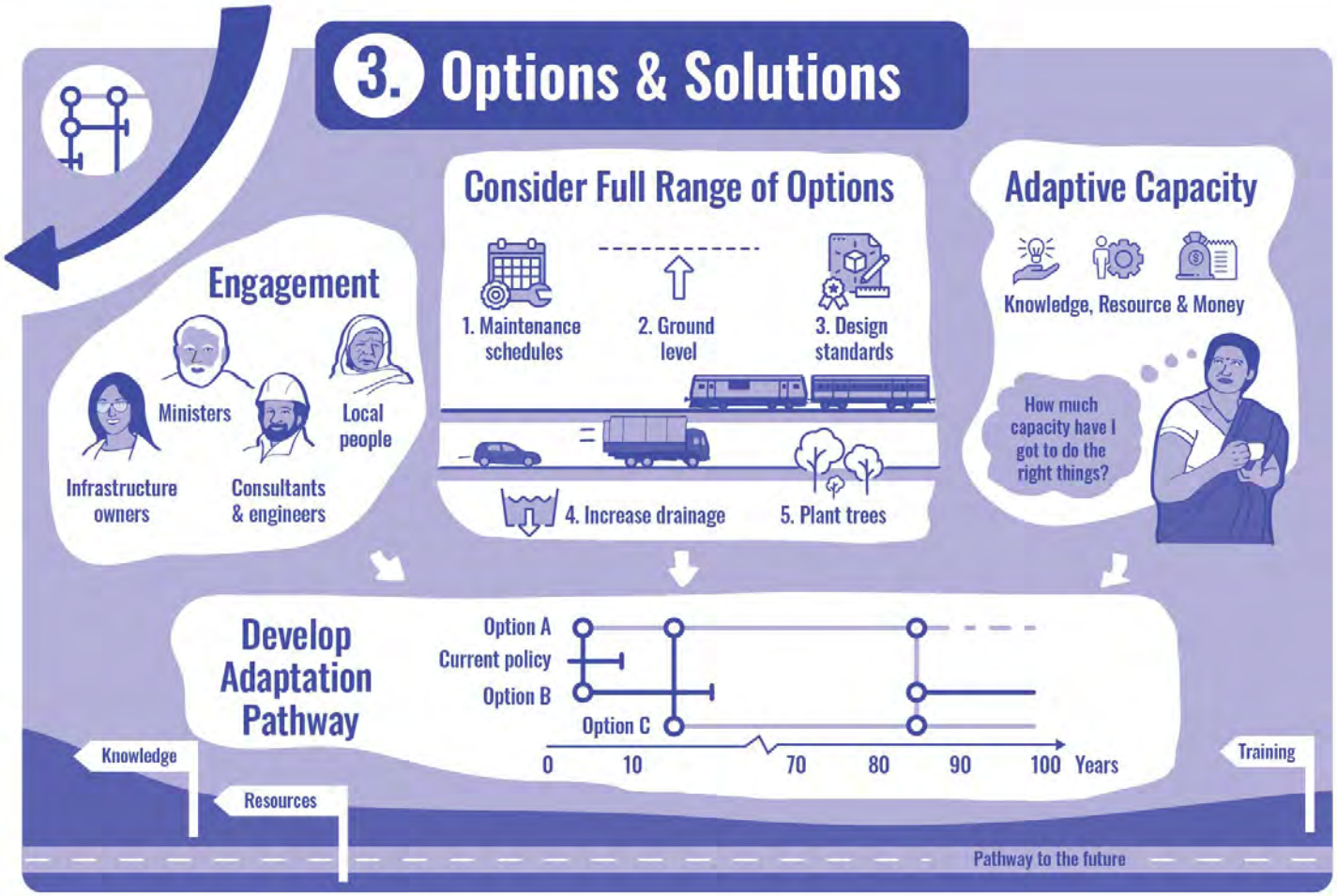

Private sector


Civil society


NGOs and charities


1. Establishing Scope
Mode
(Priorities)
Roads
Airports
Railways
Stakeholders
& Scale
Local
Regional
National
Global
Hazards
Knowledge
Tools
Collaboration
Pathway to the future
5. Review cycle every few years
4. Funding & Implementation
Sustainable
Implementation
Monitoring,
Evaluation,
Reporting &
Communication
Identify &
Secure funding
Progress Report
A 70%
B 40%
C 60%
Training
Behaviours
Tools
Pathway to the future


2. Data & Analysis
Understand Past & Future Climate
Present & Future Vulnerabilities
Where are we experiencing problems that the weather is contributing to?
Priorities
Thanks for collating this information, now let's prioritise it...
Reports
Tools
Collaboration
Pathway to the future


3. Options & Solutions
Engagement
Ministers
Local people
Infrastructure owners
Consultants & engineers
Consider Full Range of Options
1. Maintenance schedules
2. Ground level
3. Design standards
4. Increase drainage
5. Plant trees
Adaptive Capacity
Knowledge, Resource & Money
How much capacity have I got to do the right things?
Develop Adaptation Pathway
Option A
Current policy
Option B
Option C
0
10
70
80
90
100
Years
Knowledge
Resources
Training
Pathway to the future

1. Establishing scope

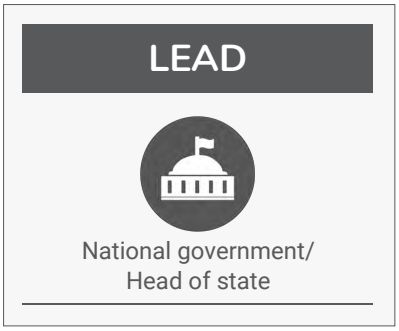
ESTABLISHING THE SCOPE OF THE PLAN TO IMPROVE TRANSPORT RESILIENCE

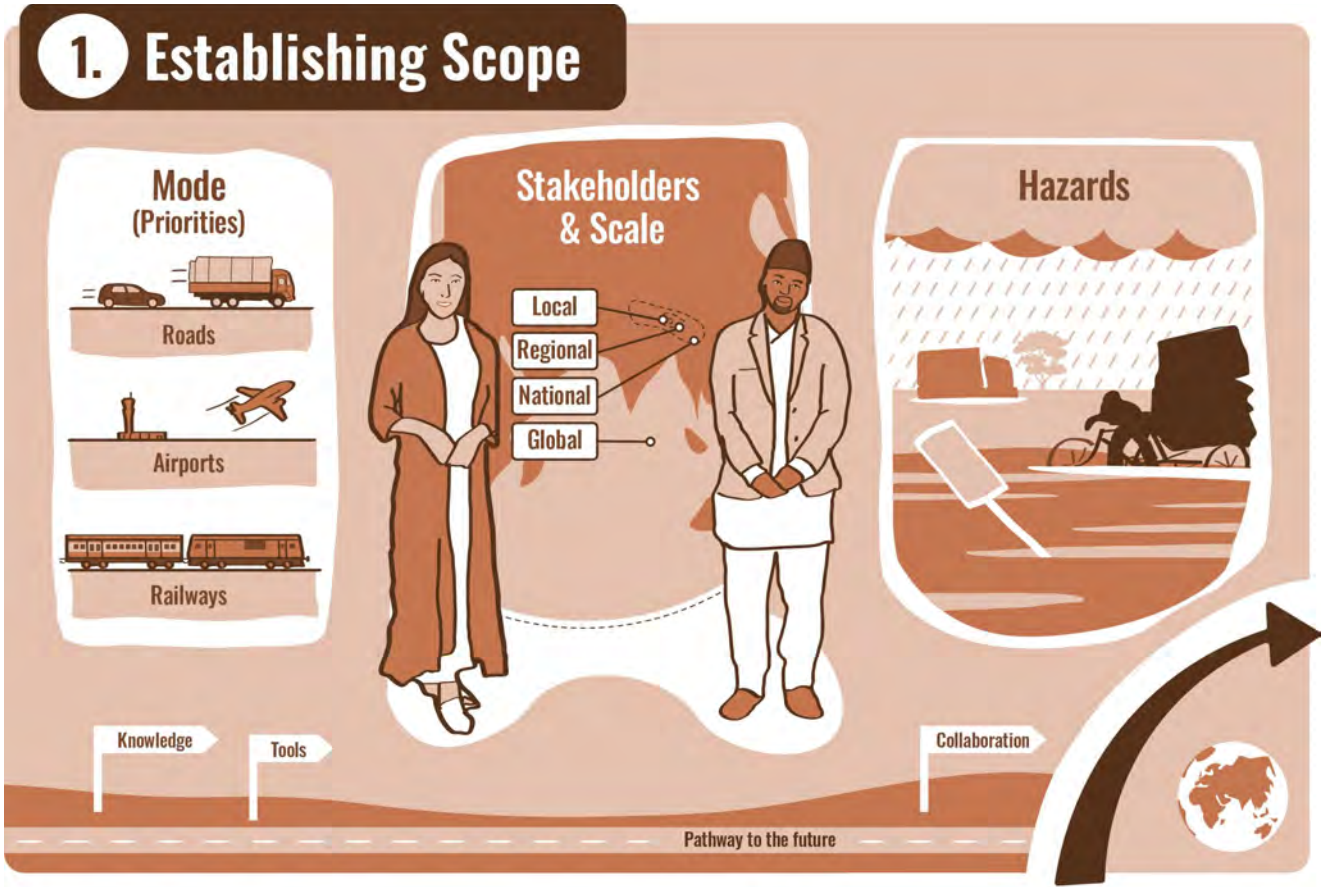
The first step is to establish the scope for transport resilience and adaptation planning. This defines boundaries that can be upheld during the process and can help prevent "scope creep" – where changes or additions to the original plan eventually make it hard, or even impossible, to manage and implement.

Coherent policy requires strong political leadership[23] as well as coordination between sectors (within and outside of government). Accountability for the design and delivery of climate change adaptation for transport resilience needs to be at the very highest level. This requires:

- Head of state recognition of climate issues and endorsement of transport resilience;
- Ministry-level commitment and accountability;
- Clearly defined agency and local level ownership and responsibility.

Establishing the scope of climate change in the context of transport resilience will help in developing adaptation objectives. These objectives should be "SMART" (specific, measurable, achievable, realistic, timely).





ESTABLISHING STAKEHOLDERS AND SCALE

Transport stakeholders should be at the heart of all stages in adaptation planning for transport resilience. Decision-making can become more effective when it involves stakeholders who are directly affected by the impacts of climate change[21]. Each stakeholder has a different role in adaptation planning, so it is important to consider when to involve them, based on the support they can offer.

It requires top-level leadership and leading ministries to bring stakeholders together. Creating a working group formalises the process.

Global: Non-governmental organisations and international bodies may provide ways of sourcing international funds, or supply resources and support, such as mode-specific tools and frameworks to help undertake analyses.

Regional: Bordering nations may participate in knowledge exchange activities that enhance adaptation planning and implementation.

National: Universities and the private sector may stimulate innovation or provide additional funding opportunities.

Local: Engaging with communities on their experiences may uncover local solutions that enhance decision-making.

SUPPORT

Environment and transport ministries

"Growing climate risks will impact the entire transport value chain, from its location, design and construction standards to the services it provides."[24]

Pierre Guislain, Senior Director, Transport & ICT, World Bank, 2015

Image: World Bank

PRIORITIES ACROSS TRANSPORT MODES

Establishing the climate-related priorities across modes of transport in order to improve transport resilience to climate change is necessary to help define boundaries. Transportation prioritisation would depend on:

- Development needs and priorities of the country;
- Current use and condition of existing transport infrastructure;
- Geographic positioning of the country in terms of international links.

Selecting climate-related priorities for transport should be a high-level exercise. Identifying the scale of the problem for different modes of transport kicks off stakeholder engagement and helps to set the boundaries of the overall process in accordance with the framework.

Decisions on whether a place, a particular climate hazard or a type of asset is a priority in delivering climate-resilient transport should include consideration of social and economic justifications, such as the reasons why people travel to a particular place, or use a particular mode. Table 3 shows some considerations for each key transport mode.

SUPPORT

Disaster risk reduction authority, Road authority, Transport operators

Critical transport links and/or hubs need to be identified. These could be major train stations, ports or airports, that are connected to multiple transport modes and other infrastructure, where any disruption could have a knock-on effect on other connections – i.e. they are interdependent. They may also be routes that provide the only link for a specific community or key site.

One method of approaching prioritisation is to use a multi-criteria analysis, where critical assets and transport links/hubs are scored numerically based on a range of socio-economic criteria and then ranked.

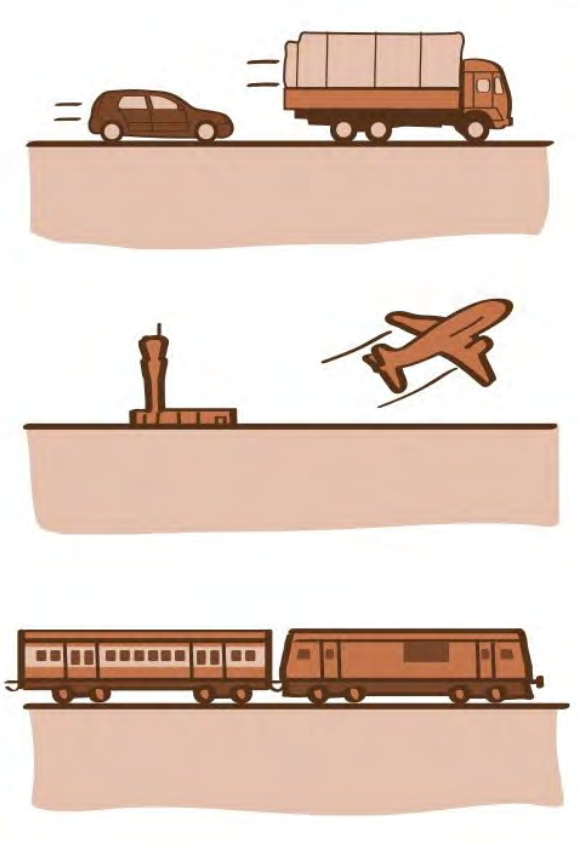


Table 3: Priority considerations for each transport mode for action on resilience to climate change

Mode	Priority considerations
Road	Primary transport option for commuters and trade; largest proportion of assets; year-round weather vulnerabilities; certain routes are of significant economic importance.
Rail	High dependency for trade; projected growth in use; major stations considered a critical hub that are an interdependency risk; expensive infrastructure assets; vulnerability to heat.
Air	High dependency on international tourism and trade for income; airports considered a critical hub that are an interdependency risk; expensive infrastructure assets.
Waterway	High dependency for certain trades (e.g. fishing); vulnerability to sea level rise and storms.
Active	Projected growth in active travel; public health risk in all severe weather, especially in urban areas.

STAKEHOLDER ENGAGEMENT IN THE UK

The Infrastructure Operators Adaptation Forum (IOAF) brings together infrastructure stakeholders from across the United Kingdom to learn from each other and work together to reduce vulnerability and identify opportunities to enhance resilience between infrastructure systems.

Member organisations include infrastructure operators, regulators, government, trade associations, professional bodies and academics in sectors such as energy, water and transport.

Coordinated by the Environment Agency, the IOAF holds regular meetings to present, share and discuss relevant developments, progress and/or challenges concerning infrastructure resilience and ways to adapt to climate change collectively. The IOAF shares international best practice and stakeholder knowledge at climate change conferences such as COP26.

Image: World Bank

IDENTIFYING THE KEY HAZARDS

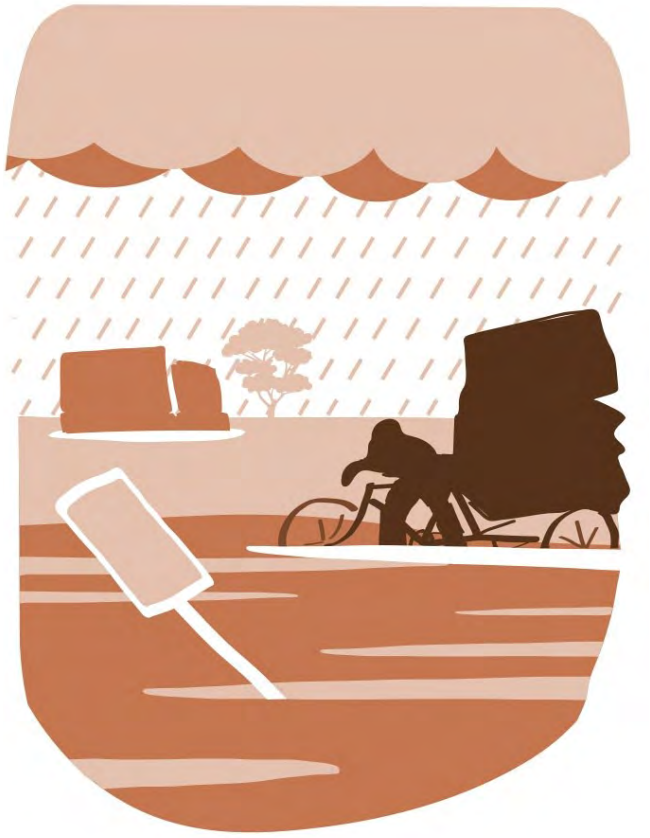
A climate hazard is a climate-related physical event that may cause loss of life, injury or other health impacts, as well as damage to infrastructure, service provision, ecosystems and/or resources. Identifying the primary weather and climate hazards will help define the boundaries and set appropriate objectives that focus efforts related to improving transport resilience. The key hazards should be ones related to the prioritised transport modes.

This activity should be a high-level exercise. It will also require input from transport specialists, however, to ensure full coverage of all transport-related impacts because they will have more technical experience.

Broadly speaking, there are five types of climate event – see pages 14 and 15. These should be considered in terms of both the transport modes that have been prioritised and the general context of the country. It will then become clearer which climate events are likely to be most problematic and therefore present the greatest hazard to the country's transport infrastructure.

Questions to consider while identifying the key hazards include:

- How old are the transport networks?
- How will the hazards affect the economy?
- Is the population likely to change or shift in any way and what are the implications?
- What might happen if these hazards worsen in future?
- Are there any interacting risks, such as multiple hazards combining to create a greater impact?
- Where are the critical transport links or hubs?



SUPPORT

Disaster risk reduction authority, Universities and research institutions, Transport operators

RESOURCES TO SUPPORT ESTABLISHING SCOPE

ISO 14090:2019 Adaptation to climate change – Principles, requirements and guidelines | www.iso.org/standard/68507.html

KE4CAP Knowledge Exchange between Climate Adaptation Platforms | https://www.weadapt.org/knowledge-base/climate-change-adaptation-knowledge-platforms/the-ke4cap-project

ND-GAIN Notre Dame Global Adaptation Initiative Country Index | https://gain.nd.edu/our-work/country-index/

Ebi et al. Scoping and Designing an Adaptation Project | https://www4.unfccc.int/sites/NAPC/Country%20Documents/General/apf%20technical%20paper01.pdf

2. Data and analysis

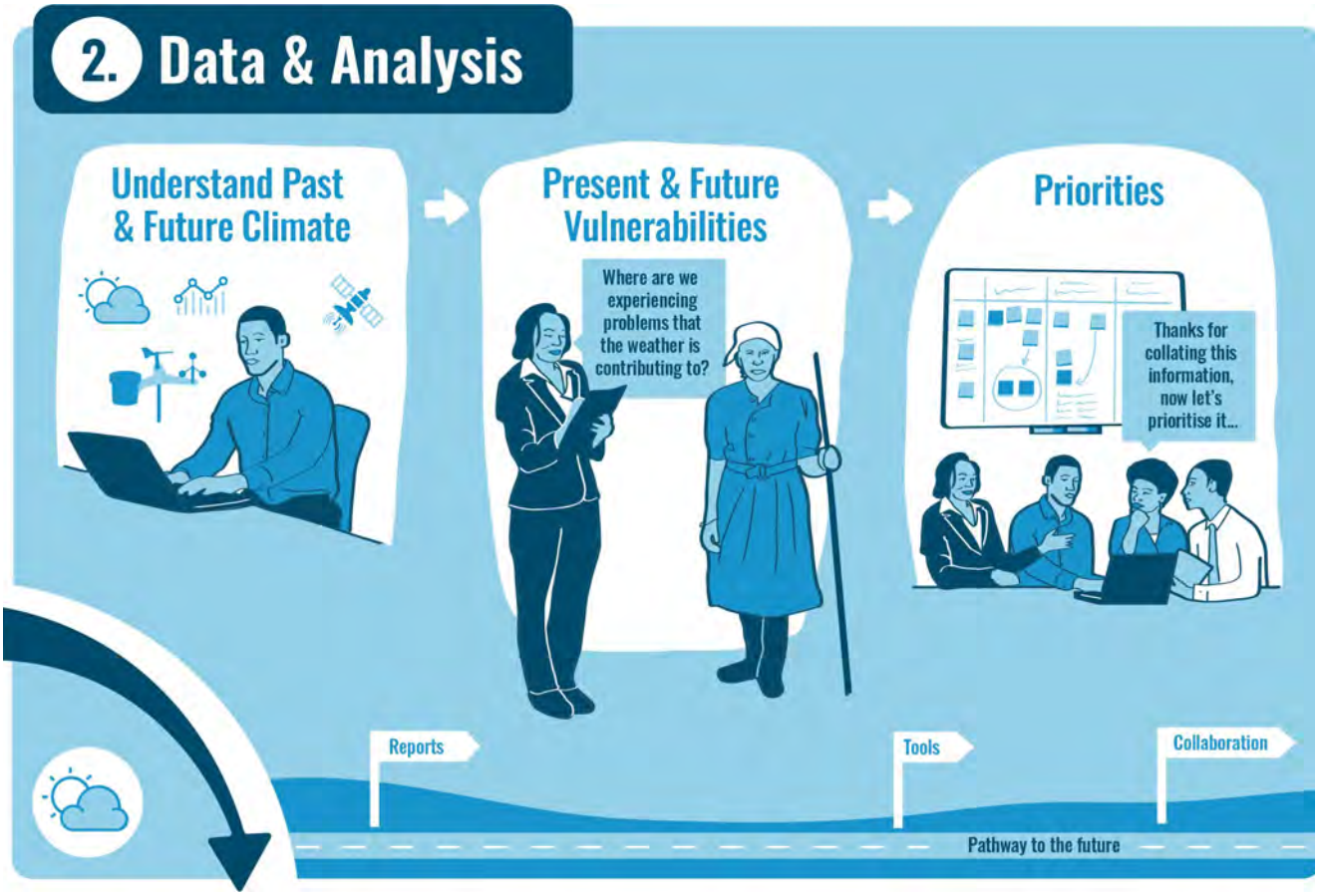
COLLECTING AND ANALYSING DATA

Good quality data is critical. It enables high quality analysis that helps identify where focus is needed to improve transport resilience. It is therefore fundamental to designing effective adaptation measures.

A wide range of data and analyses are required to make decisions about adaptation that will have a positive impact on transport resilience. Many stakeholders need to be contacted to access data, resources and tools to inform policymakers. Both environmental and transport data are necessary to analyse and understand the vulnerabilities of transport to the impacts of climate change.

Where data is not available, plans should be made in order to fund and formalise ways to collect and access data in future. Data is fundamental for creating an evidence base that can be used to support decision-making.

Undertaking data analysis for transport resilience requires a joined-up approach from environment and transport ministries. This is because they will both have a shared interest in the outcomes of such activities, as well as being the policymakers responsible for improving transport resilience.



UNDERSTANDING PAST AND FUTURE CLIMATE

Past and future climate trends need to be understood in order to assess the risks associated with climate hazards, whether they are slow onset changes or increases in frequency or intensity of extreme weather events. Transport stakeholder interviews identified that this type of data is not often formally collected or analysed.

Past climate data

Climate data is available at different scales, both spatially (global to local) and temporally (annual to hourly). The data parameters will depend on the objectives set and the prioritised transport modes and hazards; these may include air temperature, precipitation, soil moisture levels and wind velocity and direction.

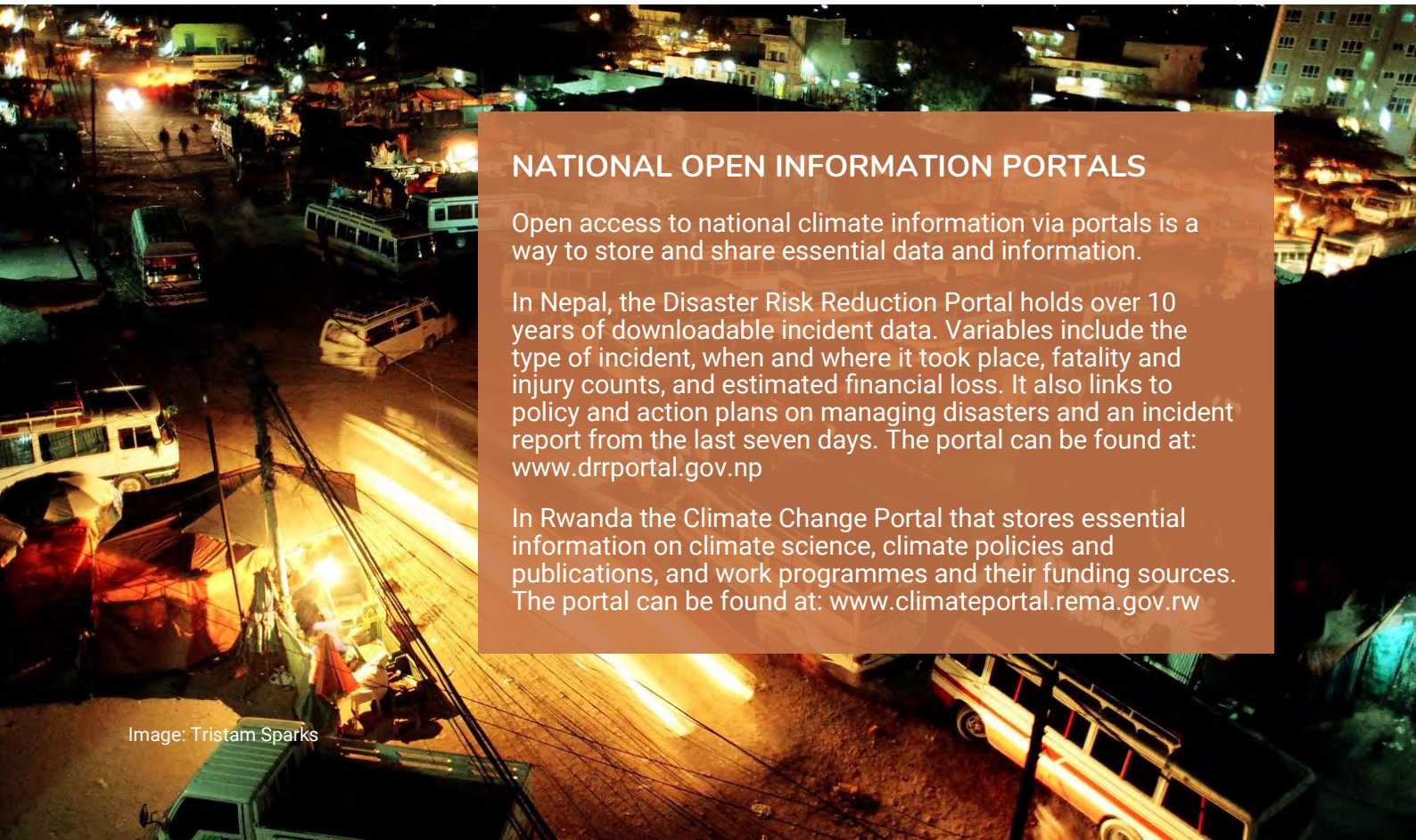
Long-term historical data will help set a baseline from which to analyse trends up to the present day. Such data may be available from supporting stakeholders, either for free or at a low cost. Suggestions for tools and resources can be found on page 35.

If data is unavailable, another option is to undertake weather impact case studies, such as identifying the financial cost of damage to transport operators due to past weather events. It is important to address any data gaps and identify ways to formalise the collection of all pertinent data as part of future planning.

Analyses of climate variables should focus on aspects such as rate of change, variability and trends in the highest and lowest values.

SUPPORT

Meteorological agency, National statistics office, Universities and research institutions



NATIONAL OPEN INFORMATION PORTALS

Open access to national climate information via portals is a way to store and share essential data and information.

In Nepal, the Disaster Risk Reduction Portal holds over 10 years of downloadable incident data. Variables include the type of incident, when and where it took place, fatality and injury counts, and estimated financial loss. It also links to policy and action plans on managing disasters and an incident report from the last seven days. The portal can be found at: www.drrportal.gov.np

In Rwanda the Climate Change Portal that stores essential information on climate science, climate policies and publications, and work programmes and their funding sources. The portal can be found at: www.climateportal.rema.gov.rw

Image: Tristam Sparks

Future climate data

The risks to infrastructure presented by the impacts of climate change may vary according to how the climate changes. Exploring possible climate scenarios and their potential impact is therefore important. The most widely used climate projections, adopted by the IPCC, are the "Representative Concentration Pathways" (RCPs). They predict mean surface temperatures across the world according to different scenarios and project how this may influence physical and socio-economic factors, such as maximum daily temperature and heat health risk.

Climate projections are complex to interpret and the RCPs are global estimates. Using the right tools and resources, and getting support from stakeholders such as academia, can help to downscale estimates to the required scale.

There are four key RCPs that describe different climate futures. They estimate the mean global surface temperature change by 2100 compared with pre-industrial levels. The RCP values are labelled according to future radiative forcing values, which is the change in energy flux in the atmosphere that affects the level of earth's warming, measured as watts per square metre (W/m^2).

RCP 2.6: Significant reductions in global emissions that meet the Paris Agreement (below 2°C warming)

RCP 4.5: Global emissions peak by 2040 and then decline (2.5-3°C warming)

RCP 6.0: Global emissions peak by 2080 and then decline (3-3.5°C warming)

RCP 8.5: Limited or no reductions in global emissions (up to 5°C warming)

SUPPORT

Private sector, Civil society, NGOs and charities

PRESENT AND FUTURE VULNERABILITIES

Some parts of transport networks and their surroundings are more vulnerable to the impacts of climate change than others; these need to be identified and the risks to them assessed. For example, coastal areas may face a combination of sea level rise and extreme weather events, or mountainous regions may be vulnerable to landslips triggered by heavy rainfall. They therefore need to be addressed in the form of an assessment that combines current and future weather and climate information with the likelihood and consequences of such impacts.

Similarly, some cross-sections of society are more vulnerable to the loss of transport as a consequence of climate change. This may include poorer populations, who are more dependent on public transport, and/or women, whose travel patterns vary. Collecting data on travel patterns, and the socio-economic consequences of travel disruption across different demographics is therefore important.

Vulnerabilities may be location- or situation-specific. Engaging supporting stakeholders at local level can offer great benefits when gathering information for risk, vulnerability and impact assessments. They may be able to share their experience and observations on climate change and the impacts it has had on them.

Some vulnerability considerations include:

- What environmental hazards are closest to transport infrastructure (e.g. steep slopes, riverbanks, coastlines, tall trees)?
- Is there a potential for a multi-hazard event?
- Are there any interdependency risks (e.g. nearby power lines, water and food supplies dependent on operational transport)?
- How connected are communities to their nearest transport links?
- What parts of the transport system are the most vulnerable members of society dependent on?

Once assessment methods are confirmed, risk indicators should be developed to establish the thresholds of acceptable levels of risk.

PRIORITISING FINDINGS

Once past and future climate data and vulnerabilities are collated and analysed, the findings can be prioritised in preparation for developing the options for adaptation planning. Findings could include examples such as:

- A particular section of road that is affected frequently from flash floods after storms;
- A coastline with a major trade port and links that faces the risks of sea level rise;
- A bridge that provides the only access to a remote community;
- A railway line that services a large number of commuters.

Engaging with stakeholders linked to disaster risk reduction is particularly important in delivering adaptation for transport resilience to climate change:

Climate hazards can also lead to humanitarian disasters, and low-income countries may not have integrated the activities between the two fields.

Disaster risk reduction is focused on near-term and local response and their experience would help with prioritisation of local climate vulnerabilities.

There may be competing interests in accessing funds and resources for disaster risk reduction and climate change adaptation that can be mitigated through collaboration.

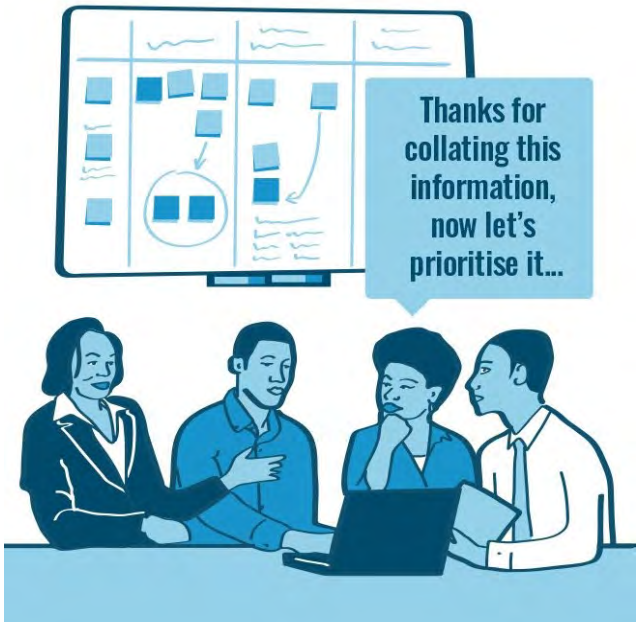
The process of prioritising these areas of need should include input from stakeholders. Because vulnerabilities may be localised, it is particularly important to discuss them with local governments. It is also important to differentiate between "quick wins" and "big wins" when prioritising.

Quick wins

Analysis may show there are vulnerabilities that could be addressed quickly because solutions are easy to implement: for example because limited costs would be incurred, little technical capacity is required or low levels of resources are necessary for delivery.

Big wins

On the other hand, analysis may reveal opportunities to make changes that would result in significant, large-scale improvements to transport resilience. These improvements could extend to socio-economic advantages. Actions resulting in big wins may require a significant period of time to implement, as well as being costly, so any prioritisation would require careful consideration.



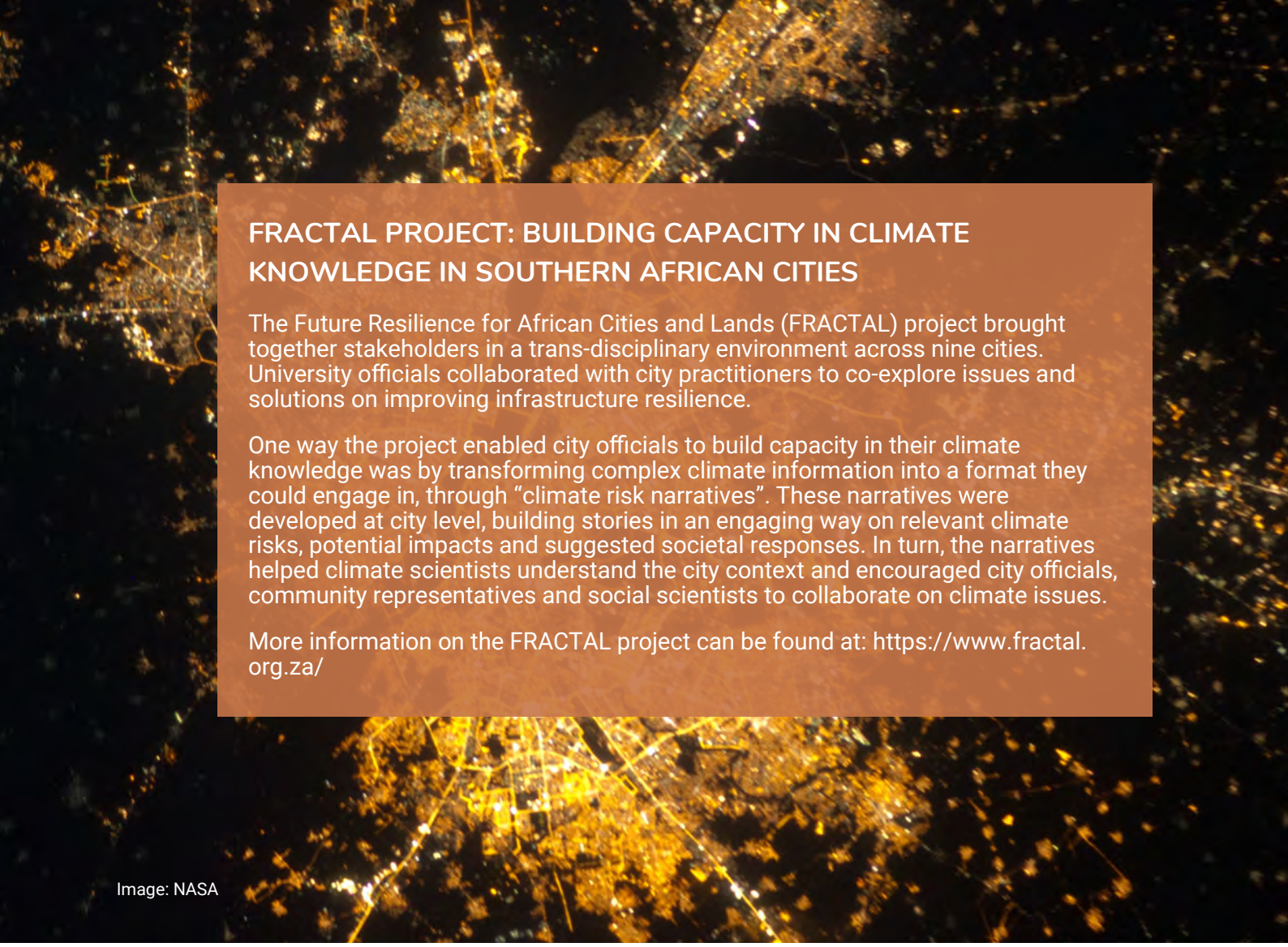


Image: NASA

FRACTAL PROJECT: BUILDING CAPACITY IN CLIMATE KNOWLEDGE IN SOUTHERN AFRICAN CITIES

The Future Resilience for African Cities and Lands (FRACTAL) project brought together stakeholders in a trans-disciplinary environment across nine cities. University officials collaborated with city practitioners to co-explore issues and solutions on improving infrastructure resilience.

One way the project enabled city officials to build capacity in their climate knowledge was by transforming complex climate information into a format they could engage in, through "climate risk narratives". These narratives were developed at city level, building stories in an engaging way on relevant climate risks, potential impacts and suggested societal responses. In turn, the narratives helped climate scientists understand the city context and encouraged city officials, community representatives and social scientists to collaborate on climate issues.

More information on the FRACTAL project can be found at: https://www.fractal.org.za/

RESOURCES TO SUPPORT DATA AND ANALYSIS

World Bank. Climate Change Knowledge Portal | https://climateknowledgeportal.worldbank.org/
World Bank. Climate and Disaster Risk Screening Tools | https://climatescreeningtools.worldbank.org/
Climate Analytics. Climate impact explorer | http://climate-impact-explorer.climateanalytics.org/
IPCC Working Group I Interactive Atlas | https://interactive-atlas.ipcc.ch/
Copernicus. Climate Data Store | https://cds.climate.copernicus.eu/
Africa RiskView (Africa only) | https://www.arc.int/africa-riskview
World Meteorological Organisation Integrated Global Observing System | https://community.wmo.int/activity-areas/wigos
World Resource Institute. Aqueduct™ Water Risk Atlas | https://www.wri.org/applications/aqueduct/water-risk-atlas
Emergency Events Database International Disaster Database | https://www.emdat.be/
C40 Cities. Climate Change Risk Assessment Guidance | https://www.c40knowledgehub.org/s/article/Climate-Change-Risk-Assessment-Guidance
Quantum GIS Open Source Desktop Geographic Information System application | https://qgis.org/en/site/about/index.html
CommunityViz Urban Analytics for Planners |https://communityviz.city-explained.com/index.html

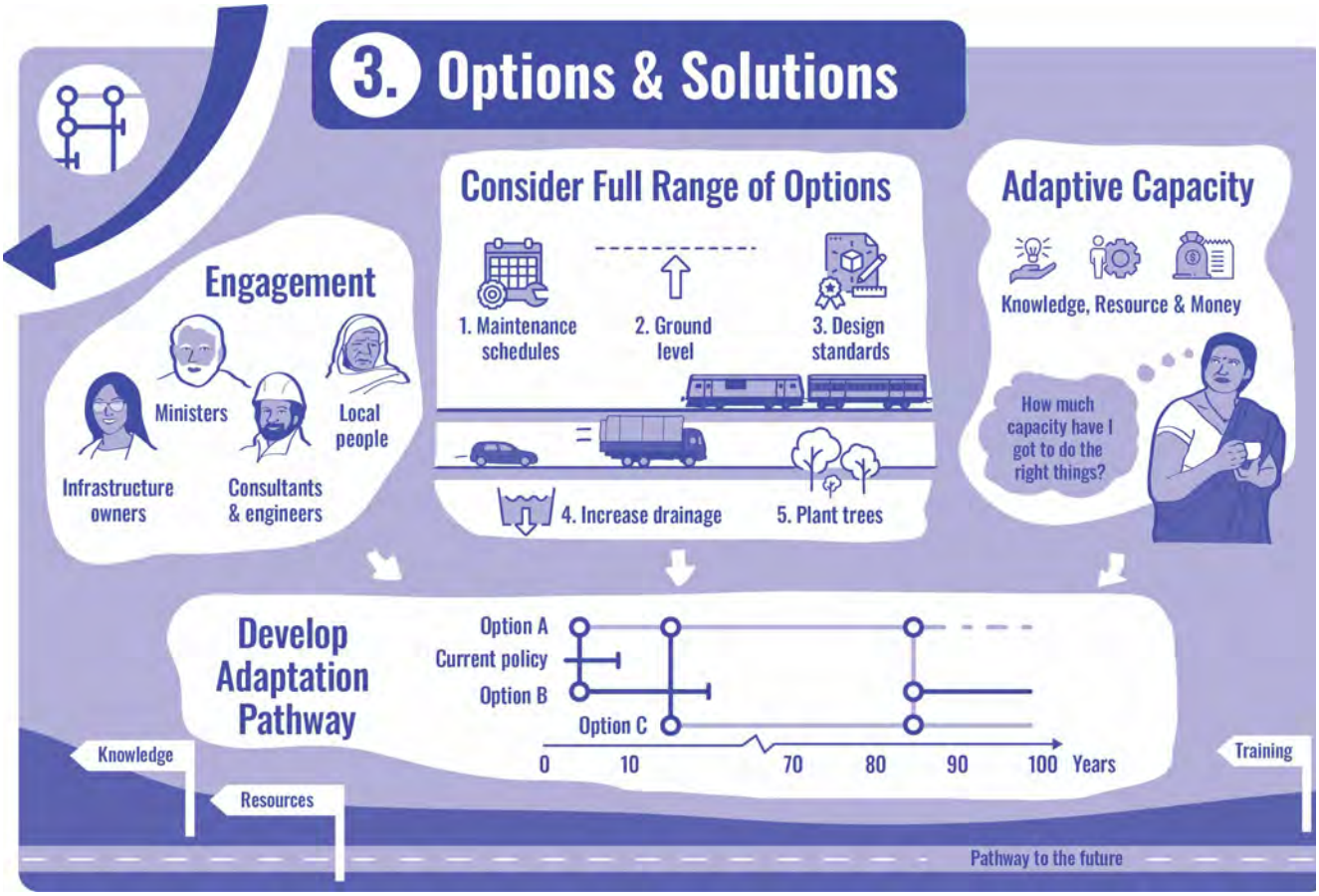
3. Options and solutions

TAKING FORWARD EFFECTIVE OPTIONS AND SOLUTIONS

Building the adaptation plan for transport resilience requires a number of decision-making steps. These should not be undertaken independently of the wide range of stakeholders, not only because of their experience and/or expertise, but also because of the impacts that the decisions may have upon them and the people they represent.

This stage of the framework is all about preparation for implementation. Decisions that feed into adaptation plans for transport resilience need to be impactful, but also realistic. They should take into account the capacities available and the environmental impact of such plans. Reducing emissions should not be independent of the adaptation decisions.

Environment and transport ministries should collaborate to lead development of an adaptation pathway (see page 43) that is holistic, with different options mapped out across time, with the overall intent being to improve transport resilience.



CONSIDER FULL RANGE OF OPTIONS

There are many ways to address each climate-related issue when it comes to transport resilience. Each may have a different lifespan and incur different costs and requirements to implement and maintain. As many of these options as possible should be considered when developing adaptation plans in order to select those that are most appropriate in the context of prioritised areas of need. Table 4 shows some examples.

No single adaptation option will improve the resilience of transport to the same climate issue everywhere. Instead, consultation with experts in the field, including researchers and transport operators, is required to tailor options to each location. Including disaster risk reduction authorities at this stage is important in order to align agendas and identify areas where reducing the impacts of natural disasters could result in both resource and cost savings.

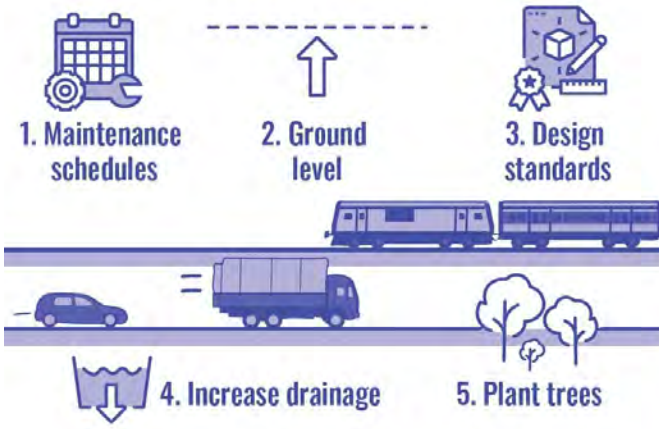


Table 4: Examples of adaptation options for transport resilience and their benefits and disadvantages

Option	Benefits	Disadvantages
Adjust maintenance schedules	Scalable, adjustable and flexible implementation; reduces likelihood of future, more expensive repairs.	May require increased human and financial resources from transport operators.
Physical infrastructure interventions e.g. raising ground	Long-lasting; significantly reduces chances of future damage (therefore high return on investment).	Requires significantly increased human and financial resources; only feasible to implement at a local scale; impacts adjacent landowners.
Update design standards	Crucial for designing climate-resilient infrastructure; large-scale impact; reduces likelihood of future, more expensive repairs.	May require increased human and financial resources from transport operators; additional costs incurred for research and training.
Increase capacities of adjacent infrastructure e.g.	Long-lasting; significantly reduced changes of future damage (therefore high return on investment).	Requires significantly increased human and financial resources; only feasible to implement at a local scale; impacts adjacent landowners.
Nature-based solutions e.g. green and blue infrastructure	Cost effective; multiple ecological and environmental co-benefits e.g. enhances biodiversity, stabilises soil and earthworks that prevents landslips and slows surface rainfall/ rates of flooding; may reduce maintenance costs.	May require increased maintenance; may be additionally impacted by other climate hazards e.g. drought, wildfires.

“[…] it is necessary to develop and implement location- and context-specific adaptation plans which seek to enhance the adaptive capacity and resilience of all stakeholders in light of their specific contexts.”[25]

Patrick C.R. Matanda, Secretary for Natural Resources, Energy and Mining, Government of Malawi, 2020

Image: Ville Miettinen

ENGAGEMENT WITH TRANSPORT STAKEHOLDERS

Consultation with transport stakeholders is critical when selecting options and solutions for transport resilience. Ultimately, they will be directly affected by any decisions, be they emergency services carrying out duties, civil society going about their day-to-day lives or private sector businesses providing goods and services to the public.

Each stakeholder will have a different perspective on the issues regarding transport resilience. These views need to be taken into account when determining the range of suitable options and solutions.

An additional benefit of engaging these stakeholders is that it raises awareness of climate change in a holistic way. Greater levels of stakeholder awareness improve their willingness to participate in adaptation planning and development and take ownership of adaptation plans when they are implemented.

Various transport stakeholders

“Our solutions must be coordinated and planned using a menu of cost-effective tools so as to build and facilitate climate-proof growth.”[26]

Brenson S. Wase, Minister of Finance, Republic of the Marshall Islands, 2019

Image: Daniela Hartmann

ASSESSING ADAPTIVE CAPACITY

Adaptive capacity is defined by the IPCC as:

"*The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.*"[3]

In the context of adapting transport to climate change, "adaptive capacity" denotes what is currently in place to cope with the potential impacts of climate change. The process of identifying what is in place, such as existing capacities, policies, strategies and plans, is referred to as "stocktaking".

Low-income countries may have lower levels of adaptive capacity than high- or middle-income countries, but this does not mean that realistic action cannot be taken. Stocktaking will identify both the gaps and the opportunities that can be built on to match actions in the adaptation plan.

Understanding a country's adaptive capacity at a national scale will require input from across different levels of government. Stocktaking should include a review of the capacities of supporting stakeholders, in terms of knowledge, resources and money, to provide a comprehensive picture of where any gaps are and to understand whether the government has sufficient capacity in every area. The types of questions to consider include:

Knowledge

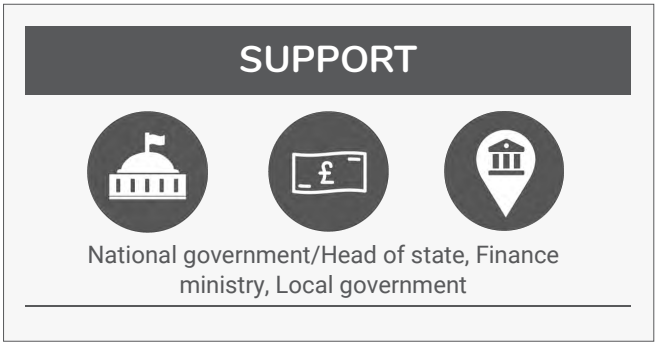
- Do all the relevant stakeholders hold the appropriate level of knowledge on climate change and how it impacts transport infrastructure?
- Is existing knowledge shared among stakeholders? How is this knowledge stored and shared?
- Do all stakeholders know where to access and share further relevant knowledge?

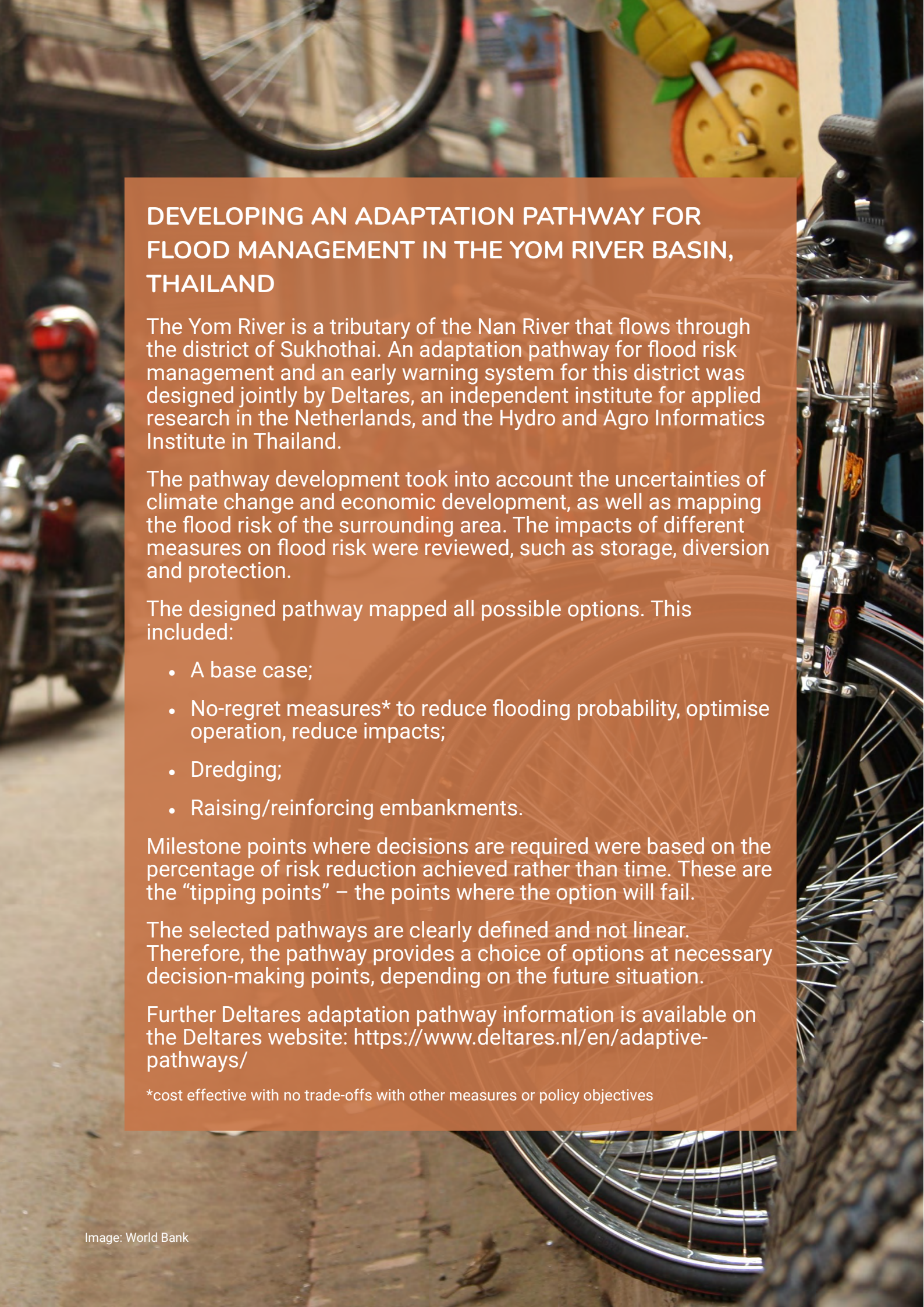
Resources

- Are tools being used to support decision making? Are they fit for purpose (at the right scale, providing sufficient data, easy to use)?
- Are these tools accessible by all stakeholders who would benefit from using them?
- Are supporting policies, strategies and plans aligned to what is needed to improve transport resilience without compromise?
- Do all relevant stakeholders have enough human resource to implement the plans?

Money

- How much money is available to spend on adaptation planning for transport resilience?
- Is it appropriately distributed e.g. at the right level and among the right stakeholders?
- Are all stakeholders aware of where additional financial resources can be found?
- Are all relevant stakeholders trained on how to apply for or access additional financial resources?





DEVELOPING AN ADAPTATION PATHWAY FOR FLOOD MANAGEMENT IN THE YOM RIVER BASIN, THAILAND

The Yom River is a tributary of the Nan River that flows through the district of Sukhothai. An adaptation pathway for flood risk management and an early warning system for this district was designed jointly by Deltares, an independent institute for applied research in the Netherlands, and the Hydro and Agro Informatics Institute in Thailand.

The pathway development took into account the uncertainties of climate change and economic development, as well as mapping the flood risk of the surrounding area. The impacts of different measures on flood risk were reviewed, such as storage, diversion and protection.

The designed pathway mapped all possible options. This included:

- A base case;
- No-regret measures* to reduce flooding probability, optimise operation, reduce impacts;
- Dredging;
- Raising/reinforcing embankments.

Milestone points where decisions are required were based on the percentage of risk reduction achieved rather than time. These are the “tipping points” – the points where the option will fail.

The selected pathways are clearly defined and not linear. Therefore, the pathway provides a choice of options at necessary decision-making points, depending on the future situation.

Further Deltares adaptation pathway information is available on the Deltares website: https://www.deltares.nl/en/adaptive-pathways/

*cost effective with no trade-offs with other measures or policy objectives

Image: World Bank

CREATING AN ADAPTATION PATHWAY

Adaptation pathways exist within adaptation plans to provide different routes, or "pathways" to account for future uncertainty and thereby improve overall resilience to climate change. Drafting multiple pathways according to different hypothetical situations is beneficial for low-income countries because it is impossible to accurately predict future developments. Having multiple pathways also allows the incorporation of short-, medium- and long-term options in the same plan.

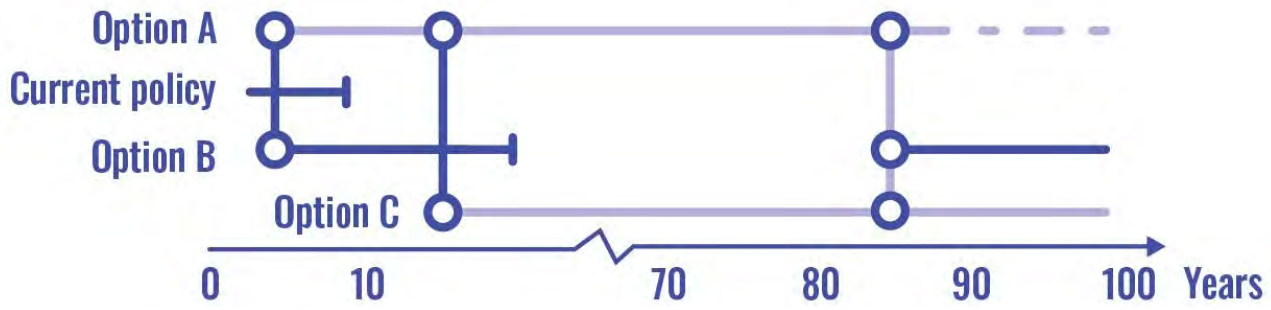
Adaptation pathways are flexible and can be approached in different ways. One might be a holistic pathway for national policy on transport resilience. Others could be more localised or climate-specific, such as individual pathways on flood risk management for roads, heat risk for railways or transport resilience to weather and climate for a particular region or city.

An adaptation pathway is a powerful communication tool, as it helps stakeholders visualise the challenges and solutions, and view the bigger picture of transport resilience needs. Designing an adaptation pathway is a long-term commitment and will therefore require the support of stakeholders who would be directly affected by the decisions made, such as local governments. It would also be beneficial to engage disaster risk reduction authorities, so they can align their response plans with each pathway's options.

Research institutions and academic specialists in adaptation pathways can provide technical consultancy in formulating the pathways and detecting the "tipping points", where one option would no longer be viable or helpful (e.g. due to cost, age or worsening climate) and needs to be replaced.

SUPPORT

Disaster risk reduction authority, Local government, Universities and research institutions



RESOURCES TO SUPPORT OPTIONS AND SOLUTIONS

BSI 8631:2021. Adaptation to climate change. Using adaptation pathways for decision making. Guide | https://shop.bsigroup.com/products/adaptation-to-climate-change-using-adaptation-pathways-for-decision-making-guide

Coast Adapt, 2017. What is a pathways approach to adaptation? | https://coastadapt.com.au/pathways-approach

United Nations Framework Convention on Climate Change. National Adaptation Plans 2020: Progress in the formulation and implementation of NAPs | https://unfccc.int/sites/default/files/resource/NAP-progress-publication-

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2016. SNAP Stocktaking for National Adaptation Planning | https://www.adaptationcommunity.net/download/ms/mainstreaming-tools/giz_snap_EN_v161114.pdf

UN Habitat, 2014. Planning for climate change: A strategic, values -based approach for urban planners | https://unhabitat.org/sites/default/files/download-manager-files/1402562124wpdm_Planning%20for%20Climate%

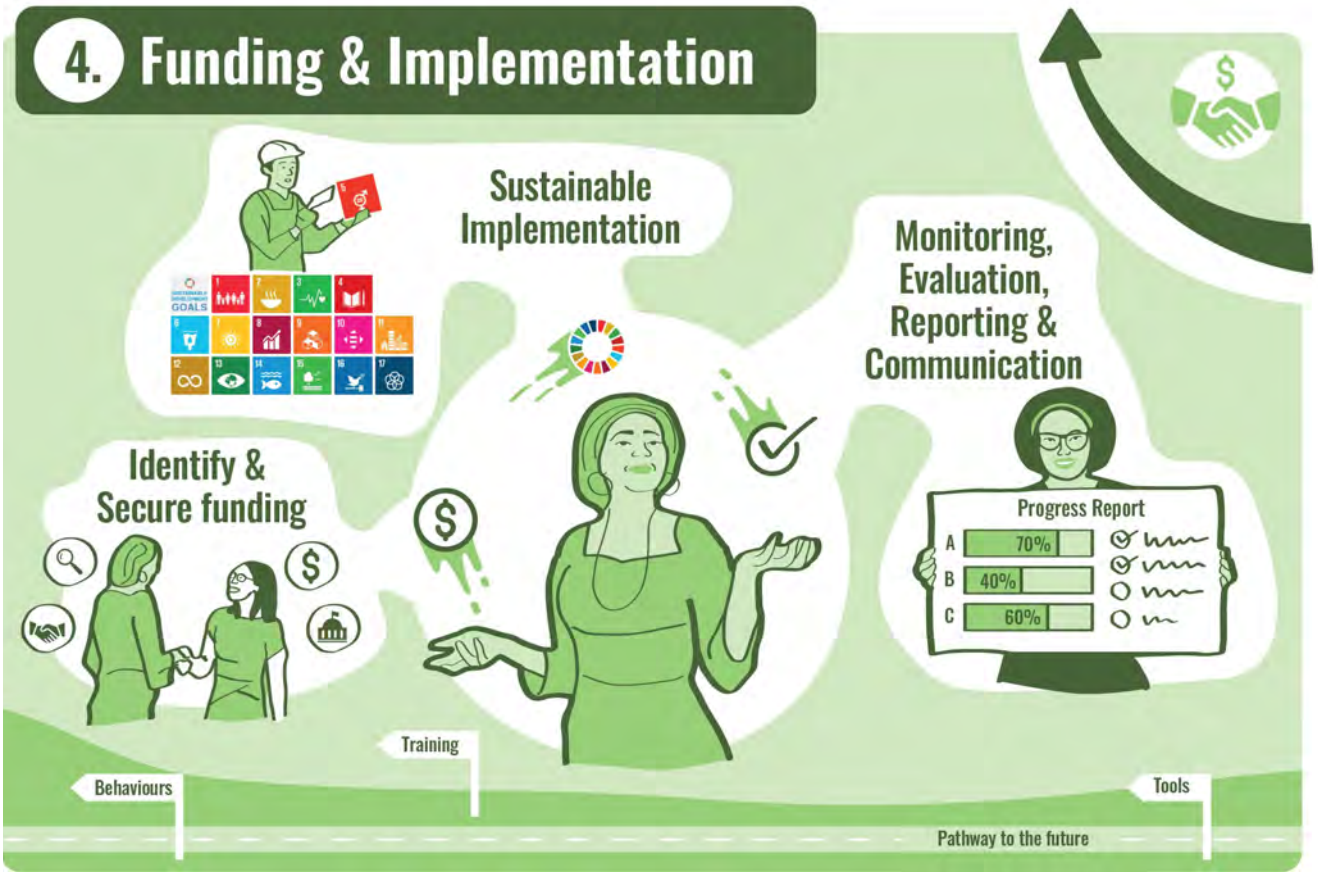
4. Funding and implementation

SOURCING FUNDS FOR SUSTAINABLE IMPLEMENTATION AND MONITORING

Turning the adaptation plan for transport resilience into actions requires three core processes: securing appropriate levels of funding; developing an implementation plan that is sustainable; and having a robust process to monitor and evaluate the process. The last of these should include ways to take action where there are problems with implementation and to communicate progress to all interested parties.

In the past, there have been adaptation funds for many infrastructure projects, but few were focused specifically on transport. However, with global pledges to increase funds for adaptation following COP26, there are now opportunities to develop these for the benefit of low-income countries.

Environment and transport ministries should be responsible for overseeing the funding and implementation processes. However, they will require extensive amounts of input and collaboration with different stakeholders to gain knowledge, access financial resources, implement plans efficiently and monitor accurately.



IDENTIFYING AND SECURING FUNDING

Investing now in adaptation for transport resilience will save money in the future. Low-income countries may have limited domestic budgets from which to allocate funds for climate resilience. However, there are many different sources of funding available to implement such adaptation, because the infrastructure sector is a key recipient of adaptation funds.

Much funding in the past has focused on reducing emissions. However, more attention is now being paid to the need to adapt, improve resilience and reduce losses and damage.

Mobilising finances for adaptation for transport resilience will require support from the finance ministry, as it will have more resources and/or capacities than the transport or environment ministries, which are expected to lead the implementation of the plans.

There are also benefits in consulting with disaster risk authorities to check if any of their projects (and funds) have similar objectives to the adaptation plan. They may be competing for the same funds, so aligning implementation or working together towards the same objective would save costs.

SUPPORT

Finance ministry, Private sector, Disaster risk reduction authority

Image: David Brossard

FONERWA: RWANDA'S GREEN CLIMATE FUND

FONERWA is the mechanism by which Rwanda accesses climate finance. Its contributions come from environmental fines and fees, proceeds from environmental revenues and seed financing from domestic stakeholders.

The fund works by issuing public calls for proposals every six months. There is a one-month window for applicants to submit project concepts according to pre-established criteria, and these are then assessed through a rigorous screening process.

Further information on FONERWA can be accessed here: https://cidt.org.uk/wp-content/uploads/2014/11/fonerwa_brochure_web.pdf04_S.pdf

The private sector is under-utilised as a source of funds for adaptation. Only 1.6% of all global adaptation finance came from private sources in 2017-2018[27], but their involvement could provide additional funds, drive adaptation innovation and solutions and help to grow technical capacities.

The private sector may not be aware of the opportunities available by getting involved in adaptation for transport resilience. Before approaching potential private sector funders to raise awareness, public sector officials may first need additional training to increase their own knowledge on climate change.

Incentivising the private sector to participate in adaptation may require grants, subsidies and de-risking of any impacts related to their investments. New or adapted policies may therefore be necessary to facilitate private sector participation. This action may benefit multiple sectors and would require input from multiple stakeholders.

The impacts of climate change on transport infrastructure are often local and may require local stakeholders to secure funds to implement adaptation plans. Stakeholders will need to know where and how to apply for these funds, necessitating training. Insurance loans, for example, focus on micro, small and medium enterprises and low-income households[28]; funds from multilateral and bilateral sources are accessed via application through regional and nationally accredited and implementing entities, such as:

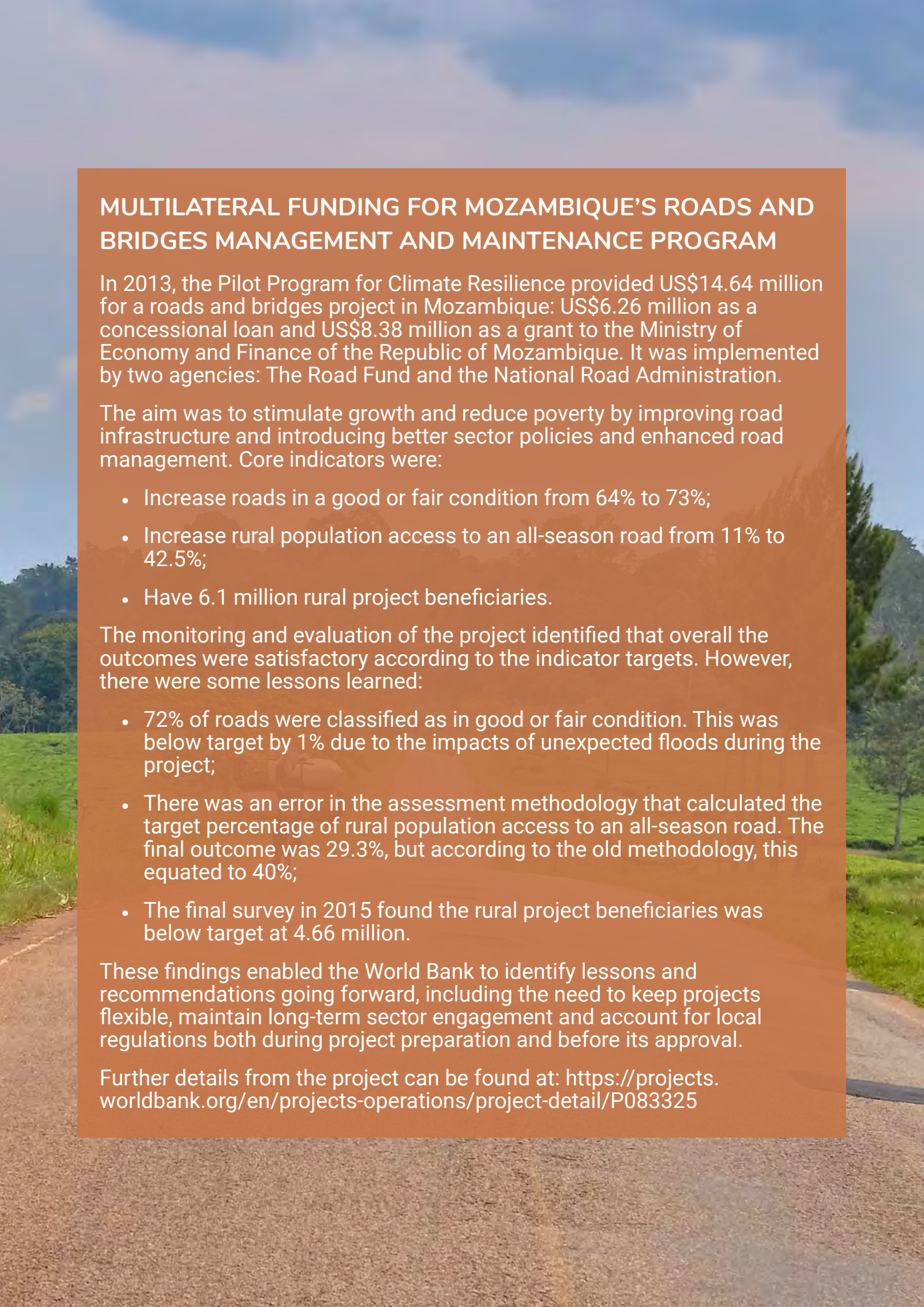
- Mali Climate Fund;
- Rwanda's Green Climate Fund;
- Bangladesh Climate Change Trust Fund.

Details of resources to support accessing and applying for funding are on page 51.

Table 5: Types of climate finance relevant to adaptation for transport resilience, how they work and examples

Type	Description	How it works	Examples
Multilateral funding	Organisations that rely on financial contributions of their member states	Flows from donors to the organisations, accessed through accredited entities	Global Climate Change Alliance, Adaptation Fund, Green Climate Fund
Bilateral funding	Transfer of funds from one state or country to another	Direct agreements flowing from donors, accessed through accredited entities	Foreign affairs ministries, Global Climate Change Alliance (EU), USAID (USA)
Insurance linked loans	Loans including insurance pay-outs and technical support should a specific climate event occur	Proposal application by recipient country that meets the criteria of funder	InsuResilience Investment Fund
Private sector investment	Funds supplied by private citizens, corporations and philanthropic organisations	Developing public-private partnerships through incentivising the private sector	National or local businesses

Image: Rod Waddington



MULTILATERAL FUNDING FOR MOZAMBIQUE'S ROADS AND BRIDGES MANAGEMENT AND MAINTENANCE PROGRAM

In 2013, the Pilot Program for Climate Resilience provided US$14.64 million for a roads and bridges project in Mozambique: US$6.26 million as a concessional loan and US$8.38 million as a grant to the Ministry of Economy and Finance of the Republic of Mozambique. It was implemented by two agencies: The Road Fund and the National Road Administration.

The aim was to stimulate growth and reduce poverty by improving road infrastructure and introducing better sector policies and enhanced road management. Core indicators were:

- Increase roads in a good or fair condition from 64% to 73%;
- Increase rural population access to an all-season road from 11% to 42.5%;
- Have 6.1 million rural project beneficiaries.

The monitoring and evaluation of the project identified that overall the outcomes were satisfactory according to the indicator targets. However, there were some lessons learned:

- 72% of roads were classified as in good or fair condition. This was below target by 1% due to the impacts of unexpected floods during the project;
- There was an error in the assessment methodology that calculated the target percentage of rural population access to an all-season road. The final outcome was 29.3%, but according to the old methodology, this equated to 40%;
- The final survey in 2015 found the rural project beneficiaries was below target at 4.66 million.

These findings enabled the World Bank to identify lessons and recommendations going forward, including the need to keep projects flexible, maintain long-term sector engagement and account for local regulations both during project preparation and before its approval.

Further details from the project can be found at: https://projects.worldbank.org/en/projects-operations/project-detail/P083325

SUSTAINABLE IMPLEMENTATION

Implementing adaptation options requires a plan that documents all the processes and actions required to deliver each option within the scope of adaptive capacity. It should set out explicitly who is responsible for delivering each part of the adaptation plan. It should also identify contingencies in case any part of the plan cannot be delivered. The overall plan should be owned and endorsed by top government leadership, such as the head of state.

The implementation plan should demonstrate how it aligns with other strategies, policies and plans that relate to it, such as:

- National/city/local development plans;
- Disaster risk reduction plans;
- Transport strategies;
- Zero emissions plans;
- Sustainable Development Goals.

It is important that implementation is sustainable, which means that any actions should not be detrimental to the environment or society. Adaptation for transport resilience also needs to complement other sustainability plans. Examples include:

- Accessing local materials for construction;
- Involving civil society in local projects;
- Enhance plans by increasing the use of nature-based solutions such as blue and green infrastructure;
- Provide sufficient training to all necessary stakeholders.

MONITORING AND EVALUATION

Monitoring and evaluation is essential in increasing transport resilience because it helps assess the progress of implementation. Where progress is unsatisfactory, for example in terms of speed and/or quality, the monitoring and evaluation processes should pick up problems early enough to allow corrective action to be taken.

Progress should be formally documented and made accessible for learning. This is valuable information for stakeholders because it provides evidence for the future of managing adaptation and transport resilience. The frequency of undertaking monitoring and evaluation should be determined at the start, as well as a process for any necessary ad hoc monitoring and evaluation, such as when new information is available or new technology is developed.

Setting baseline indicators for specific actions prior to implementation is highly beneficial for monitoring and evaluation. Quantitative indicators are preferable, as they can be easily understood by stakeholders and can help with visualising progress.

Examples of indicators in Rwanda's national adaptation plan[29]:

% local government unit participation

% compliance to codes of practice

No. of personnel completed training courses

% coverage by early warning system

SUPPORT

National government/Head of state, Local government, Disaster risk reduction authority

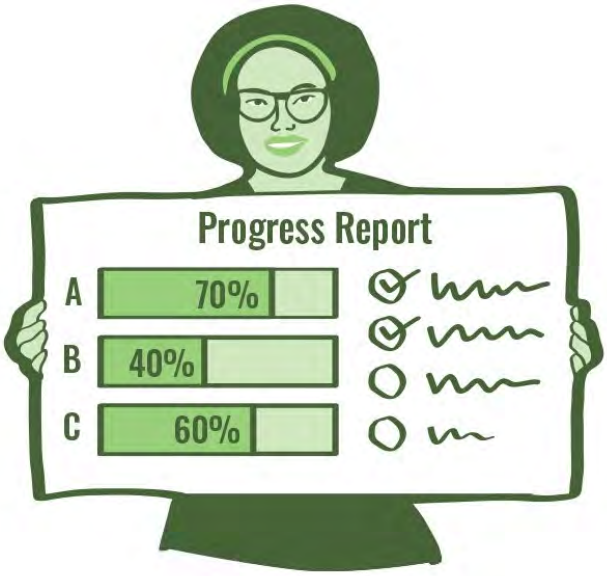
REPORTING AND COMMUNICATION

Reporting on adaptation plans and progress towards implementation is important in order to inform stakeholders about the outcomes of their support and maintain their interest and involvement in improving transport resilience.

Communications on how transport resilience is improving should be free for anyone to access and provided in a clear and understandable manner for the public. To gain maximum exposure, it is beneficial to make these available through a variety of media outlets, such as:

- Publishable reports on government and relevant stakeholders' websites;
- National and local television;
- Local and national newspapers;
- Social media platforms;
- Community newsletters.

The supporting stakeholders' purpose here is to raise the profile of the adaptation plans and their implementation. For example, the head of state could present details of progress via an outlet organised by the communications ministry.



SUPPORT

National government/Head of state, Communications ministry

RESOURCES TO SUPPORT FUNDING AND IMPLEMENTATION

Climate Funds Update | https://climatefundsupdate.org/

OECD, 2015. Toolkit to Enhance Access to Adaptation Finance | https://www.oecd.org/environment/cc/Toolkit%20to%20Enhance%20Access%20to%20Adaptation%20Finance.pdf

Adaptation Fund, 2009. Accessing Resources from the Adaptation Fund – The Handbook | https://www.preventionweb.net/files/13786_Handbook.English1.pdf

Acclimatise and Climate & Development Knowledge Network, 2020. Green Climate Fund Proposal Toolkit | http://www.acclimatise.uk.com/wp-content/uploads/2020/06/GCF-Funding-Proposal-Toolkit-2020.pdf

UNCDF, 2019. Financing local adaptation to climate change: Experiences with performance-based climate resilience grants | https://www.uncdf.org/article/4483/financing-local-adaptation-to-climate-change

CADD: Capacity Diagnosis and Development | https://www.cadd.global/

OECD, 2021. Strengthening adaptation-mitigation linkages for a low-carbon, climate-resilient future | https://www.oecd-ilibrary.org/environment/strengthening-adaptation-mitigation-linkages-for-a-low-carbon-climate-resilient-future_6d79ff6a-en

GIZ. Toolbox for Adaptation Monitoring and Evaluation (scroll down to the click-through gear-wheel infographic under "A Toolbox for Adaptation M&E") | https://www.adaptationcommunity.net/monitoring-evaluation/

5. Review cycle

ADAPTATION FOR TRANSPORT RESILIENCE AS AN ITERATIVE PROCESS

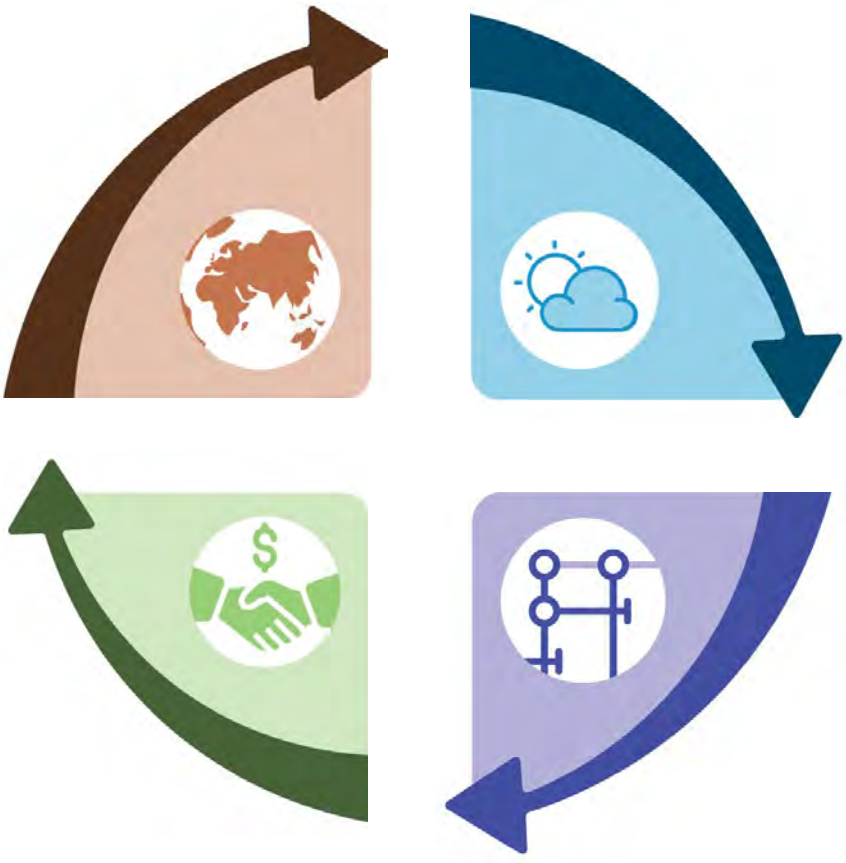
The overall process of improving transport resilience for climate adaptation is not fixed; instead, it should be iterative. As the climate continues to change and infrastructure developments grow, the plans in place may require adjusting or changing. Maintaining an ongoing process will reinforce the concept of adaptation as a "business as usual" practice and ensure continued resilience of transport to climate change.

Nevertheless, a timeline should be agreed for completion of the whole process and for it to start again. Some national adaptation plans allocate around five years to undertake their proposals, from inception to completion and evaluation.

This policy guide advocates the use of adaptation pathways, which is a long-term approach to adapting to climate change. A framework cycle (which is shorter) can be integrated into an adaptation pathway by building multiple review cycles into the pathway that align with critical decision-making points. That way, interim goals are set alongside the longer-term, over-arching goal of adaptation for transport resilience; these shorter-term, interim goals are more manageable in the near-term.

The outcomes of monitoring and evaluation in one cycle can inform the scope of the first step of a framework for the next cycle. It is therefore important that monitoring and evaluation is well documented and details are stored securely.

The capacity to create and implement adaptation for transport resilience should grow through each cycle as funds obtained are used to provide training, improve technical skills and build better relationships among stakeholders. The process should also allow for the introduction of new or additional stakeholders who can bring new insights or knowledge – for example, a new public transport operator in a rapidly growing city.



Next steps

The next steps in co-ordinating an adaptation plan and policies to improve transport resilience should include most or all of the following actions.

ESTABLISH THE SCOPE OF THE PLAN TO IMPROVE TRANSPORT RESILIENCE

Define the transport resilience strategy or plan

- Set out how the plan will be formulated (e.g. part of the national adaptation plan, or as separate transport-focused plan).

Establish a cross-sector dialogue

- Form a sector working group for transport resilience: ensure all relevant stakeholders are informed and establish an annual meeting schedule;
- Designate the head of state or a relevant senior minister to chair the working group.

Determine adaptation objectives

- Set objectives in accordance with prioritisations by modes and identified key hazards;
- Ensure objectives are aligned with other related strategies, plans and policies.

COLLECT AND ANALYSE DATA

Obtain all necessary data from a range of stakeholders and formally review trends

- Seek out data on past weather and climate, climate projections and vulnerabilities (e.g. infrastructure, environmental, socio-economic);
- Collect local data where possible using appropriate tools and through consultation with relevant stakeholders;
- Formulate plans to collect essential data in future where it is currently unavailable.

Undertake impact/risk/vulnerability assessments

- Establish a method and risk indicators;
- Assess likelihoods and consequences using the method and indicators.

Prioritise outcomes collaboratively

- Identify “quick wins” – those to action quickly;
- Identify “big wins” – those with the greatest benefits.

Formalise data collection and access for stakeholders

- Establish a policy for key stakeholders responsible for transport infrastructure (e.g. transport operators, local government) to collect necessary data;
- Facilitate a centralised repository for data access for all transport stakeholders.

TAKE FORWARD EFFECTIVE OPTIONS AND SOLUTIONS

Engage with stakeholders in developing and selecting options and solutions

- Use outcomes from analyses to brainstorm all possible solutions in each priority area;
- Invite stakeholders to workshops and consultations on selection of options;
- Utilise available tools and resources;
- Agree necessary policies that support the delivery of the selected options.

Create a plan using an adaptation pathways approach

- Consider short-, medium- and long-term options over their entire lifespans;
- Plan different pathways for a range of options and scenarios (e.g. accounting for variance in future funds or rate of climate change);
- Document the plan, including any justifications and assumptions for decisions.

SOURCE FUNDS FOR SUSTAINABLE IMPLEMENTATION AND MONITORING

Access and apply for funding opportunities

- Review government capabilities for applying for multilateral, bilateral and insurance-linked loan support;
- Seek out tools and resources to train staff;
- Incentivise private sector involvement through policy levers (e.g. grants);

Formulate an implementation plan

- Assign roles and responsibilities to actions;
- Ensure it aligns with other related plans;
- Set baselines and goals for progress.

Report and communicate on adaptation progress

- Formalise monitoring and evaluation processes and store results securely;
- Ensure reports and updates are accessible.

REVIEW THE PROCESS

Establish a timescale for the entire process

- Document a clear time schedule for all parts of the plan.

Integrate into the adaptation pathway

- Allocate periodic process cycles to the timeline.

“Science must lead in shaping the national and local policy and planning agenda for the long haul. The integration of science in our development and policy planning agenda can only help us face better what we know and what is yet to be fully understood.”[30]

Renato Redentor Constantino, Executive Director, Institute for Climate and Sustainable Cities, 2021

Image: Laurent de Walick

RESOURCES AND FURTHER READING

This list of resources and further reading provides additional guidance to support improvements in transport resilience to climate change. Although it is not a comprehensive list, it provides more information on lessons learnt and best practice in various countries relating to climate change adaptation.

General Guidance

2030 Agenda for Sustainable Development: The 17 Goals | https://sdgs.un.org/goals

ADB. Asian Transport Outlook Database | https://data.adb.org/dataset/asian-transport-outlook-database

CDRI, 2021. Mainstreaming Climate Adaptation for Creating Resilient Infrastructure: Technical Note | https://www.cdri.world/sites/default/files/publication/Mainstreaming%20Climate%20Adaptation%20for%20Creating%20Resilient%20InfrastructureTechnical%20Note.pdf

AfTR-CC Project State of Knowledge Report | https://transport-links.com/download/state-of-knowledge-report-adaptation-for-transport-resilience-to-climate-change-aftr-cc-for-lics-in-africa-and-south-asia/

IDB, 2020. Increasing infrastructure resilience with Nature-based Solutions | https://publications.iadb.org/publications/english/document/Increasing-Infrastructure-Resilience-with-Nature-Based-Solutions-NbS.pdf

IPCC, 2018. Special report: Global Warming of 1.5°C. Summary for Policymakers | https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

KE4CAP: Knowledge Exchange between Climate Adaptation Knowledge Platforms, first published 2019 | https://www.weadapt.org/knowledge-base/climate-change-adaptation-knowledge-platforms/the-ke4cap-project

OECD, 2016. Adapting Transport to Climate Change and Extreme Weather: Implications for Infrastructure Owners and Network Managers | https://www.oecd.org/publications/adapting-transport-to-climate-change-and-extreme-weather-9789282108079-en.htm

The Resilience Shift. Infrastructure Pathways | https://www.resilienceshift.org/infrastructure-pathways/

UNCTAD, 2021. Sustainable and resilient transport amidst rising uncertainty, disruptions and climate risks | https://sdgpulse.unctad.org/sustainable-transport/

UNCTAD, 2019. Ad Hoc Expert Meeting on Climate Change Adaptation for International Transport: Preparing for the Future | https://unctad.org/meeting/ad-hoc-expert-meeting-climate-change-adaptation-international-transport-preparing-future

UNDRR, 2020. Disaster Risk Reduction and Climate Change Adaptation: Pathways for policy coherence in Sub-Saharan Africa | https://www.undrr.org/publication/disaster-risk-reduction-and-climate-change-adaptation-pathways-policy-coherence-sub

UNDRR, 2015. Sendai Framework for Disaster Risk Reduction 2015-2030 | https://www.preventionweb.net/files/resolutions/N1516716.pdf

UNDRR. PreventionWeb Knowledge Base | https://www.preventionweb.net/knowledge-base/latest-additions

UNECE, 2020. Climate Change Impacts and Adaptation for Transport Networks and Nodes | https://unece.org/fileadmin/DAM/trans/doc/2020/wp5/ECE-TRANS-283e.pdf

UNECE, 2014. Climate Change Impacts and Adaptation for International Transport Networks | https://unece.org/DAM/trans/main/wp5/publications/climate_change_2014.pdf

UNESCAP, 2020. Virtual Expert Group Meeting on Climate Change mitigation and adaptation for transport in Asia and the Pacific | https://www.unescap.org/events/virtual-expert-group-meeting-climate-change-mitigation-and-adaptation-transport-asia-and

UNFCCC, 2021. Climate Action Pathway, Transport: Vision and Summary | https://unfccc.int/sites/default/files/resource/Transport_Vision%26Summary_2.1.pdf

UNFCCC, 2021. Climate Action Pathway, Transport: Action Table | https://unfccc.int/sites/default/files/resource/Transport_ActionTable_2.1.pdf

WMO, 2021. Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970-2019) | https://library.wmo.int/index.php?lvl=notice_display&id=21930

World Bank, 2015. Moving Toward Climate-Resilient Transport: The World Bank's Experience from Building Adaptation into Programs | https://openknowledge.worldbank.org/handle/10986/23685

Roads

PIARC, 2015. International climate change adaptation framework for road infrastructure | https://www.piarc.org/en/order-library/23517-en-International%20climate%20change%20adaptation%20framework%20for%20road%20infrastructure

ReCAP. Climate Adaption: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa | https://www.research4cap.org/index.php/regional-and-cross-regional-projects/climate-adaption

World Bank, 2017. Integrating Climate Change into Road Asset Management: Technical Report | https://openknowledge.worldbank.org/handle/10986/26505

World Bank, 2016. Enhancing the Climate Resilience of Africa's Infrastructure: The Roads and Bridges Sector | https://www.worldbank.org/en/topic/transport/publication/enhancing-the-climate-resilience-of-africas-infrastructure-the-roads-and-bridges-sector

Railways

RSSB, 2016. Tomorrow's Railway and Climate Change Adaptation | https://www.rssb.co.uk/en/research-catalogue/CatalogueItem/T1009

UIC, 2017. Rail Adapt: Adapting the railway for the future | https://uic.org/IMG/pdf/railadapt_final_report.pdf

Ports and Inland Waterways

PIANC, 2020. Climate Change Adaptation Planning for Ports and Inland Waterways | https://www.pianc.org/publications/envicom/wg178

UNCTAD, 2021. Climate Change Impacts and Adaptation for Coastal Transport Infrastructure: A compilation of Policies and Practices | https://unctad.org/system/files/official-document/dtltlb2019d1_en.pdf

Urban Transport

C40 Cities Knowledge Hub | https://www.c40knowledgehub.org/s/global-search/%40uri?language=en_US

TUMI, 2021. Adapting Urban Transport to Climate Change | https://www.transformative-mobility.org/assets/publications/SUTP_Sourcebook5f-2_AdaptingTransport-to-ClimateChange.pdf

Design Standards and Guidance

BSI 8631:2021. Adaptation to climate change. Using adaptation pathways for decision making. Guide | https://shop.bsigroup.com/products/adaptation-to-climate-change-using-adaptation-pathways-for-decision-making-guide

ISO 14090:2019 Adaptation to climate change – Principles, requirements and guidelines | www.iso.org/standard/68507.html

Climate Resilience Toolboxes

Climate Analytics. Tools | https://climateanalytics.org/tools/

NDC Partnership. Climate toolbox | https://ndcpartnership.org/ndc_toolbox_navigator

The Resilience Shift. Resilience Toolbox | https://www.resilienceshift.org/tools/

UNCTAD. SIDSport-ClimateAdapt | https://sidsport-climateadapt.unctad.org/

World Bank. Climate Change Knowledge Portal | https://climateknowledgeportal.worldbank.org/

GLOSSARY

Adaptation: The process of adjustment to actual or expected climate and its effects, in order to moderate or avoid harm or exploit beneficial opportunities.

Adaptation pathway: A decision-making strategy to address adaptation, made up of a sequence of manageable steps or decision-points over time. It may have multiple pathways in order to account for uncertainties.

Adaptive capacity: The ability to adjust to potential damage, to take advantage of opportunities or respond to consequences.

Blue infrastructure: Usually refers to water assets or infrastructure that support sustainable drainage.

Climate emergency: A situation in which urgent action is required to reduce or halt climate change and the damage resulting from it.

Climate hazard: The occurrence of a climate-related physical event that may cause loss of life, injury or other health impacts, as well as damage to infrastructure, service provision, ecosystems and/or resources.

Climate impact: The effect of climate hazards on natural and human systems.

Climate risk: The potential for consequences, represented as the likelihood of occurrence of climate hazards.

Climate vulnerability: The sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Green infrastructure: Multi-functional green spaces or features that deliver quality of life and environmental benefits for communities.

Nature-based solutions: Actions to protect, sustainably manage and restore natural or modified ecosystems.

Transport resilience: The capacity of a transport system to cope with a hazardous event.

ACRONYMS

FRACTAL	Future Resilience for African Cities and Lands
GDP	gross domestic product
GIZ	German Society for International Co-operation
IOAF	Infrastructure Operators Adaptation Forum
IPCC	Intergovernmental Panel on Climate Change
NDC	nationally determined contribution
RCP	representative concentration pathway
SDG	Sustainable Development Goals

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3. IPCC. Climate Change 2014: Synthesis Report [Cited: 19 Oct 2021] https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

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CLIMATE-RESILIENT TRANSPORT

POLICY GUIDE

FCDO High Volume Transport

Climate-resilient transport is vital to ensure its users now, and in future, are able to maintain acceptable standards of living. It depends on the commitment of everyone who is engaged in transport to ensure this need is met. This policy guide draws on best practices worldwide and provides a framework, with clear actions, to support effective decision-making on the planning and implementation of transport systems that are more resilient to the impacts of climate change.

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