Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa

Change Management Guidelines

Council for Scientific and Industrial Research (CSIR), Paige-Green Consulting (Pty) Ltd and St Helens Consulting Ltd

ReCAP Project GEN2014C

August 2019

Preferred citation: Head, M., Verhaeghe B., Maritz, J., Council for Scientific and Industrial Research (CSIR), Paige-Green Consulting (Pty) Ltd and St Helens Consulting Ltd (2019). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa, Change Management Guideline, GEN2014C. London: ReCAP for DFID.

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Cover Photo: Benoît Verhaeghe

Quality assurance and review table

Version	Author(s)	Reviewer(s)	Date
1	M. Head, B. Verhaeghe	L. Sampson & Dr J. Cook, ReCAP PMU	August 2017
2	M. Head, B. Verhaeghe, J. Maritz	N. Leta, ReCAP PMU Dr J. Cook, ReCAP TP	November 2018
3	M. Head, B. Verhaeghe, J. Maritz	J. Haule & N. Leta, ReCAP PMU Dr J. Cook, ReCAP TP	May 2019
4	M. Head, B. Verhaeghe, J. Maritz	Prof R.L. Wilby	July 2019
5	M. Head, B. Verhaeghe, J. Maritz	N. Leta, ReCAP PMU	September 2019

ReCAP Database Details: Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa

Reference No:	GEN2014C	Location	Sub-Saharan Africa
Source of Proposal	DFID/ReCAP	Procurement Method	Tender
Theme	Sustainability of access	Sub-Theme	Climate resilience
Lead Implementation Organisation	CSIR	Partner Organisations	Paige-Green Consulting St Helens Consulting
Start Date	April 2017	End Date	September 2019
Report Due Date	August 2019	Date Received	August 2019

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Abstract

The African Development Bank states that Africa is one of the regions in the world that are most vulnerable to the impacts of climate change. The majority of both vulnerability-led and scenario-led studies carried out in the region suggest that damages from climate variability and change, relative to population and Gross Domestic Product, could be higher in Africa than in any other region in the world.

In order to help address this significant threat to Africa's development, the Africa Community Access Partnership (AfCAP) (a research programme funded by UK Aid) commissioned a project that started in April 2016. Its aim was to produce regional guidance and to advance climate-resilient rural access in Africa through research and knowledge sharing within and between participating countries. The output should assist the development of a climate-resilient road network that reaches fully into and between rural communities.

The study focused on: (a) appropriate engineering and non-engineering adaptation procedures; (b) sustainable enhancement of the capacity of three AfCAP partner countries to deal with the likely impacts of climate change on rural road networks; (c) sustainable enhancement of the capacity of additional AfCAP partner countries; and (d) uptake and embedment of research outputs across AfCAP partner countries.

A Climate Adaptation Handbook has been developed that provides relevant information and guidance on climate adaptation procedures for rural road access, along with a methodology to address climate threats and asset vulnerability. The Guideline presented in this document acts as a supporting document to the Climate Adaptation Handbook and aims specifically at providing change management guidelines relating to non-engineering adaptation options.

Change management with respect to Climate Change has the potential for making significant strides towards creating resilience to climate effects in a cost-effective way. The Change Management Guidelines covers policy and planning, stakeholder and asset management, and proposes recommendations for the formulation of strategies and programmes for improvement.

Key words

Capacity Building; Change Management; Climate Adaptation; Climate Change; Climate Impact; Climate Resilience; Climate Threat; Climate Variability; Risk; Rural Access; Vulnerability.

Research for Community Access Partnership (ReCAP)

Safe and sustainable transport for rural communities

ReCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa and Asia. ReCAP comprises the Africa Community Access Partnership (AfCAP) and the Asia Community Access Partnership (AsCAP). These partnerships support knowledge sharing between participating countries in order to enhance the uptake of low-cost, proven solutions for rural access that maximise the use of local resources. The ReCAP programme is managed by Cardno Emerging Markets (UK) Ltd.

www.research4cap.org

Glossary (as defined by the Intergovernmental Panel on Climate Change, IPCC, 2018)

Accessibility	The ease for population groups to reach or participate in service activities using a transport network.
Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities (i.e. actions that reduce hazard, exposure and vulnerability). In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.
Adaptive Capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
Adaptation Needs	The circumstances that arise when the anticipated risks or experienced impacts of climate change require action to ensure the safety of populations and the security of assets and resources, including ecosystems and their services.
Adaptation Options	The array of strategies and measures that is available and appropriate for addressing adaptation. They include a wide range of actions that can be categorized as structural, institutional, ecological or behavioural, amongst many others
Build back better	An approach to post-disaster recovery that reduces vulnerability to future disasters and builds community resilience to address physical, social, environmental, and economic vulnerabilities and shocks
Capacity Building	The ability to enhance the strengths and attributes of, as well as the resources available to, an individual community, society or organisation in response to change.
Change Management	A collective term for all approaches to preparing and supporting individuals, teams, and organisations in making organisational or institutional changes in order to equip them to address and resolve new or recurring challenges impacting on them and their stakeholders (e.g., impacts of climate variability and change on their operations).
Climate Change	Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.
Climate Variability	Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system such as ocean-atmosphere coupling (internal variability), or to variations in natural or anthropogenic external forcing such as variations in solar output or changing concentrations of greenhouse gasses (external variability).

Disaster	Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread and adverse human, material, economic or environmental effects that require immediate emergency responses to satisfy critical human needs and that may require external support for recovery.
Early Warning Systems (EWS)	The set of technical, financial and institutional capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss. Dependent upon context, EWS may draw upon scientific and/or Indigenous knowledge.
Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected by hazards.
Extreme Weather Event	An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season).
Flood	The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, groundwater floods, and glacial lake outburst floods.
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.
Impacts (Consequences, Outcomes)	The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial.
Impact Assessment	The practice of identifying and evaluating, in monetary and/or nonmonetary terms, the effects of [climate] change on natural and human systems.
Likelihood	The chance of a specific outcome occurring, where this might be estimated probabilistically.

Lock-in	The concept of 'lock-in' pertaining to climate change: decisions made now about the location, design and operation of assets will determine their long term resilience to the effects of climate change.
Mobility	The ability to move people and goods efficiently and effectively for socio-economic activities between an origin and destination using a transport network.
Resilience	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.
Risk	The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence.
Risk Assessment	The qualitative and/or quantitative scientific estimation of risks.
Risk Management	Plans, actions or policies to reduce the likelihood and/or consequences of risks or to respond to consequences.
Road Criticality	Road criticality refers to the importance of a rural access road to the communities it serves in terms of the community's dependence on a road for accessing markets, goods and services.
Stressors	Events and trends, often not climate-related, that have an important effect on the exposed system and that can increase vulnerability to climate-related risk.
System Sensitivity	The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise).
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
Vulnerability Assessment	Process that attempts to identify the root causes for a system's vulnerability (to climate variability and change).

Acronyms, Units and Currencies

°C	Degrees Celsius
$	United States Dollar
ADB	Asian Development Bank
AfCAP	Africa Community Access Partnership
AfDB	African Development Bank
AM	Asset Management
AsCAP	Asia Community Access Partnership
BPC	Bipartisan Policy Centre
C-FIT	Climate Finance Impact Tool (JICA)
CCAP	Climate Change Action Plan (AfDB)
CMIP5	Coupled Model Inter-comparison Project Phase 5
CRED	Centre for Research on the Epidemiology of Disasters
CRMA	Climate Risk Management and Adaptation (AfDB)
CSIR	Council for Scientific and Industrial Research, South Africa
CSS	Climate Safeguard System (AfDB)
DANIDA	Danish International Development Agency
DFID	Department for International Development (UK)
DMC	Developing Member Country (ADB)
EBRD	European Bank for Reconstruction and Development
EU	European Union
GIS	Geographic Information System
IDA	International Development Association
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IRI	International Roughness Index
JICA	Japan International Cooperation Agency
LoS	Level of Serviceability
MCA	Multi-Criteria Analysis
MDA	Ministry, Department and/or Agency/Authority
NDP	Nordic Development Fund
NGO	Non-Government Organisation
ODA	Official Development Assistance (JICA)
RAMS	Road Asset Management System
ReCAP	Research for Community Access Partnership
SMS	Slope Management System
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, DFID)
UN ESA	United Nations, Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reconstruction

Executive Summary

Africa's development is highly dependent on an adequate and reliable roads system that also can withstand the impacts of climate change. To help address the significant threat of climate change to Africa's development, the Africa Community Access Partnership (AfCAP), a research programme funded by UKAid, commissioned a project in April 2016 to produce regional guidance on the adaptation of rural access roads to climate change. The project aims to provide pragmatic, cost-beneficial engineering and non-engineering adaptation procedures and guidance to road sector institutions through research and knowledge sharing within and between participating African countries.

The study covers climate threats and adaptation for both existing and new infrastructure. It addresses the issues of appropriate and economic methodologies for vulnerability and risk assessments; prioritisation of adaptation interventions; and optimisation of asset resilience in the context of low-volume rural access roads. In addition, it provides evidence of cost-, economic- and social-benefit links to rural communities arising from more resilient rural access to support wider policy adoption across Africa.

The study focuses on the following:

a) Demonstration of appropriate engineering and non-engineering adaptation procedures
b) Sustainable enhancement of the capacity of three AfCAP partner countries[1] (i.e. Ethiopia, Ghana and Mozambique) to deal with the likely impacts of climate change on rural road networks – these three countries represent nearly the full range of climatic systems in sub-Saharan Africa
c) Sustainable enhancement of the capacity of additional AfCAP partner countries
d) Uptake and embedment of research outputs across AfCAP partner countries.

The Handbook on Climate Adaptation[2] provides a methodology for carrying out a climate adaptation assessment for rural access to support socio-economic sustainability. It also focuses on those activities and actions that conventional engineering standards and procedures do not necessarily cover. The Handbook is supported by three separate guideline documents that cover the following:

- Change Management
- Climate Risk and Vulnerability Assessment[3] – this guideline takes users through the steps involved in conducting a risk and vulnerability assessment at national-/district-level, as well as a local-/project-level risk and vulnerability study when implementing new or maintaining/retrofitting existing infrastructure.
- Engineering Adaptation[4] – this guideline introduces primary climatic attributes and the potential effects of these, followed by the provision of suggested adaptation measures for each infrastructure component, also highlighting the critical importance of effective drainage provision and of timely and appropriate maintenance of road assets.

The guideline document in hand is a supporting document that deals with change management related to climate change adaptation. It covers, inter alia, policy and planning, stakeholder and asset management, and recommendations for the formulation of strategies and programmes for improvement. As such, this Guideline targets especially decision makers in government at national, provincial/state and district level.

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[1] The AfCAP Partner Countries currently consist of the Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Liberia, Malawi, Mozambique, Sierra Leone, South Sudan, Tanzania, Uganda and Zambia.

[2] Head, M., Verhaeghe, B., Paige-Green, P., le Roux, A., Makhanya, S. and Arnold, K. (2019). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Climate Adaptation Handbook,* GEN2014C. London: ReCAP for DFID.

[3] Le Roux, A., Makhanya, S., Arnold, K. and Roux, M. (2019). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Climate Risk and Vulnerability Assessment Guidelines,* GEN2014C. London: ReCAP for DFID.

[4] Paige-Green, P., Verhaeghe, B. and Head, M. (2019). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Engineering Adaptation Guidelines,* GEN2014C. London: ReCAP for DFID.

1 Background and Context

1.1 Aims and objectives

The overall project aim is to advance previous AfCAP research and to sustainably enhance the capacity of AfCAP partner countries to reduce current and future climate impacts on vulnerable rural infrastructure. The study covers threats and adaptation options for both existing and new infrastructure – through research, and consequent uptake and embedment, at both policy and practical levels, of pragmatic, cost-beneficial engineering and non-engineering procedures, based on the recognition of locally specific current and future climate threats.

The **fundamental** ***research objective*** of the project is to identify, characterise and demonstrate appropriate engineering and non-engineering adaptation procedures that may be implemented to strengthen the long-term resilience of rural access, based on a logical sequence of defining the following concepts:

- Climate threats
- Climate impacts
- Vulnerability to impact (risk)
- Adequacy of funding
- Non-engineering adaptations (referred to in this document as Change Management options)
- Engineering adaptations
- Prioritisation

The second objective, which focuses on ***capacity building and knowledge exchange***, is to meaningfully engage with relevant road and transport ministries, departments and agencies/authorities in a knowledge dissemination and capacity building programme based on the outputs from research being conducted.

The third objective is to ensure that there is a focus on the ***uptake and subsequent embedment*** of outcomes aimed at a range of levels – from informing national policies, through to regional and district planning, down to practical guidance on adaptation delivery at rural road levels.

It also pays attention to the management of measures that could be taken in a scenario when budgets for road construction and maintenance are inadequate or absent. It furthermore focuses on those activities and actions that conventional standard approaches may not necessarily cover.

1.2 Demonstration studies

The project was supported by demonstration studies that were conducted to assess the appropriateness and practicality of the recommended approaches for climate adaptation. These studies were carried out in three countries, namely Ethiopia, Ghana and Mozambique – countries that represent and cover most of the farming systems found in Sub-Saharan Africa (including mixed–maize, commercial and small scale farming, agro-pastoral, root crops etc.). Countries such as Mozambique are regularly subject to extreme events such as floods and tropical cyclones. Both Mozambique and Ghana are on the receiving end of water flowing out of major international river basins, with most of their economic activity and population concentrated along the coast and in low-lying deltas.

1.3 Introduction to the Climate Adaptation Handbook

The Climate Adaptation Handbook is the overarching document that provides relevant information on climate adaptation procedures for rural road access, along with instructions on an appropriate methodology for addressing climate threats and asset vulnerability, so as to increase resilience in the foreseeable future. It has been developed to cover a wide range of climatic, geomorphologic and hydrological circumstances commonly applicable to Ethiopia, Ghana and Mozambique, but equally applicable to any of the other Sub-Saharan African countries.

The Handbook illustrates the fundamental principles, processes and steps required for climate resilience. Details regarding actual adaptation measures are included in the accompanying Guideline documents covering *Change Management* (Non-engineering options), *Climate Threats and Vulnerability Assessment,* and *Engineering Adaptation*.

1.3.1 Application

Although the Handbook has been developed for *low-volume rural road applications*[5], most of the principles contained within the Handbook may also apply to *high-volume roads.* It is however important to note that the priorities and design parameters for low-volume roads may differ from those for high-volume roads and therefore caution is advised.

There are three specific overlapping applications of the Handbook in the context of low-volume roads (see Figure 1):

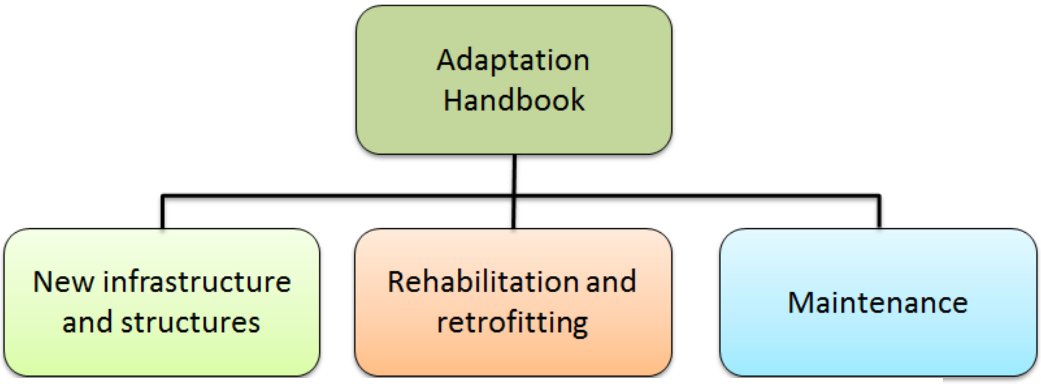

Figure 1: Applications covered in the Handbook

For the three applications, take note of the following:

- Accessibility objectives are the same, but the design and construction processes may differ.
- Principles of the adaptation methodology remain the same.
- Existing infrastructure is expected to have more historical knowledge and understanding of climatic and hydrological effects.
- In all three countries studied, maintenance backlogs of existing roads were the most problematic issue that needed resolving and thus were deemed the highest priority.
- Rehabilitation and retrofitting of vulnerable assets are the costliest operations.

New Infrastructure and structures

Overall, construction of especially new low-volume rural road infrastructure is rare. The limited funding available is mostly used for upgrading, repairs and rehabilitation, except for limited areas of realignment that are necessary to avoid congestion in cities (e.g. ring roads) or to improve geometric and safety conditions.

Although there are many initiatives to improve rural access, most of these involve the upgrading of existing tracks, earth roads or gravel roads to higher standards (but usually still low-volume), together with the improvement of existing or construction of new drainage structures.

[5] Low-volume rural roads are roads that typically carry less than 1 million equivalent standards axles (80 tonnes) over their service life.

Rehabilitation and retrofitting

In cases where the required serviceability criteria cannot be met or where future conditions are expected to lead to a disruption or failure of the infrastructure components, retrofitting of the existing facilities is required. This type of activity can, however, be costly.

Rehabilitation is also required where a structure, embankment or cutting has failed due to extreme climate effects and would need additional measures to ensure future resilience. Past inventories of such failures would support the prioritisation, design and implementation of more resilient measures.

Maintenance of existing infrastructure

Many of the potential problems related to climate susceptibility can be minimised by good maintenance practices. In most sub-Saharan countries, a significant maintenance backlog results from historical climatic events as well as an inability to fund routine maintenance. This has left parts of the infrastructure more susceptible to climate-related damage. An important part of creating resilience is to identify these areas and implement measures as soon as possible or as funding permits. There would, however, in most cases seldom be sufficient funds for the necessary measures.

Failure to address the maintenance backlogs would effectively result in a do-nothing scenario, which would require additional planning, emergency and reactive resources following projected increases in extreme events.

1.3.2 Content of the Handbook

The methodology comprises of **five stages**, with each stage covering several activities as set out in Table 1. However, these stages will be applied with slightly different rigour depending on the scale and circumstances associated with its application. For example, the stages would be applied differently at one end of the scale where there is a fully funded road corridor, compared to the opposite end of the scale where there is a district maintenance backlog, with scarce or zero funds. It is important to note that the policy and strategy directives, as well as the appropriate data support systems, might not always be in place and the level of competence to implement adaptation would therefore vary significantly. Because of this wide range of circumstances, the Handbook is split into two parts: Part A covers the ***Situational Review and Adaptation Management*** and Part B covers the appropriate ***Methodology.***

The Handbook also pays attention to the management of measures that could be taken when budgets are inadequate or absent under a specific *'Low-cost' scenario*.

This guideline document features the change management aspects in more detail. It features the items listed in Part A of the Handbook as well as parts of the methodology (see items in Table 1 highlighted in green). It does not address all aspects of the adaptation methodology, instead it focuses on the core issues affected by the introduction of climate change adaptation predominantly within relevant roads and transport ministries, departments and/or agencies/authorities (MDAs). This also extends to activities that are new to MDAs such as undertaking climate risk screening.

Table 1: Contents and scope of the adaptation methodology

Part A	**Situational review and adaptation management**
Covers:	Problem identification (including evidence) Identification of probable causes Drivers of change (policy-driven) Change management Approach and delivery Effective data management
Part B	**Methodology**
Stage 1	***Climate risk screening (national/regional)***
B.1.1	Needs determination
B.1.2	Identification and mobilisation of stakeholder/partner involvement
B.1.3	Setting of policy, objectives and scope (network level)
B.1.4	Analysis of observed and projected climate effects
B.1.5	Data gathering and risk analysis
Stage 2	***Impact and vulnerability assessment (project/local level)***
B.2.1	Project-level climate risk screening
B.2.2	Climate-sensitive impact assessments
B.2.3	Data gathering and vulnerability assessment
Stage 3	***Technical and economic evaluation of options***
B.3.1	Identification of strategies and potential adaptation measures
B.3.2	Impact assessment of 'do something' and 'do nothing'
B.3.3	Stakeholder consultations
B.3.4	Prioritisation and selection of adaptation measures
Stage 4	***Project design and implementation***
B.4.1	Development of an implementation plan (including 'Low-cost' scenario)
B.4.2	Design parameters and optimisation
B.4.3	Construction supervision and documentation
Stage 5	***Monitoring and Evaluation***
B.5.1	Development of a monitoring and evaluation plan
B.5.2	Reporting on and sharing of implementation experiences

Figure 2 illustrates the manner in which the strategic approach could vary, based on the type of activity and adequacy of funding available. Development Partner funding (shown in green) would normally be comprehensive/prioritised, whereas part-funded projects (shown in yellow) would require prioritisation that is highly selective and may, by necessity, be skeletal in the activities that can be funded. Feedback provided by AfCAP partner countries identified maintenance as being heavily underfunded or, in some cases, absent. In such cases, the activities should be based on available resources (shown in red). This strategic approach is further discussed in Section 2.3.3: *'Low-cost' scenario*; Section 2.4.4: *Adaptation management in cases of poor or inadequate budget scenarios*; Section 4.5: *'Low cost' scenario*; and Section 4.6: *Management of Delivery*.

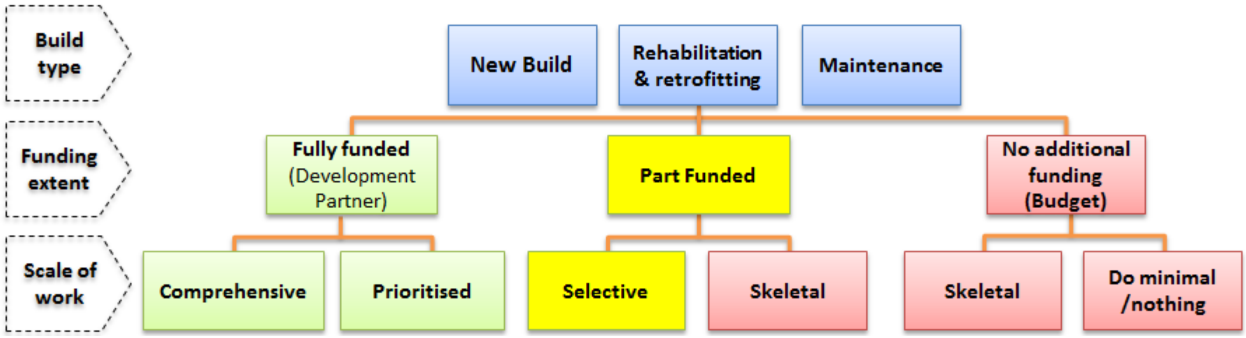

Figure 2: Strategic approach based on type of activity and adequacy of funding available

1.3.3 Using this guide

This guide document is linked to the Adaptation handbook and it also refers to other guideline documents that form part of the documentation set (see Figure 1). Sections in this report that are linked to the Handbook are marked with a green frame marker (see below).

Section linked to the **Adaptation Handbook.**

This document also contains information boxes to provide additional information or that make reference to added examples. These are indicated in shaded blue boxes (see below).

Information Box

A list of recommended actions is also placed in summary boxes that are marked orange (see below).

Recommended actions

Some remarks deal specifically with a poor, inadequate budget situation (predominantly referred to as the 'Low-cost', 'Do minimal' or 'Do nothing' scenario. See green marked boxes.

Remarks dealing with a poor, inadequate or absent budget scenario

2 Situational Review and Adaptation Management

This Section details the situational analysis and adaptation management which is summarised as **Part A in the Adaptation Handbook.**

2.1 Vulnerability and projected population

The African Development Bank (2018) states that Africa is one of the regions in the world that is most vulnerable to the impacts of climate change. The majority of both vulnerability-led and scenario-led studies carried out in the region suggest that damages from climate variability and change, relative to population and Gross Domestic Product, could be higher in Africa than in any other region in the world.

Over the past four decades (1975-2015) African countries have experienced more than a 1,400 recorded weather-related disasters (meteorological, hydrological and climatological) (CRED and UNISDR, 2015; Engelbrecht et al., 2015). These disasters have had significant impacts on countries' economies and in particular on rural communities and their livelihoods. The impacts of these natural hazards (floods, storms, droughts, extreme temperatures, landslides and wildfires) were also felt across all economic sectors and have caused destruction to energy, transport, water and sanitation infrastructure.

Many communities and countries are dependent on natural resources to sustain their livelihoods. As a result of their dependency, exposure and vulnerability, they have been particularly at risk of losing life, livelihoods and economic activity when natural hazards do occur. The high social vulnerability and low adaptive capacity of these communities, as well as their high exposure to natural hazards has resulted in the death of more than 600,000 people (95% due to droughts), left 7.8 million people homeless (99% due to flooding and storms) and affected an estimated 460 million people over the past four decades (CRED, 2016).

The African continent may be facing a potential direct liability in excess of $150 billion to repair and maintain existing roads damaged by temperature and precipitation changes directly related to projected climate change through this Century (Chinowsky et al., 2011). **This liability does not include costs associated with future impacts to critically needed new roads**, nor does it include indirect socio-economic effects and disruption of livelihoods resulting from the dislocation of communities and from loss of rural access. It is estimated that by 2050 an additional 230 million people could live in rural areas within the 15 AfCAP-supported and partner countries, making improved rural accessibility a high priority in Africa (UN ESA, 2018). Table 2 and Figure 3 next show the projected rural population growth in tabular and graphical format respectively.

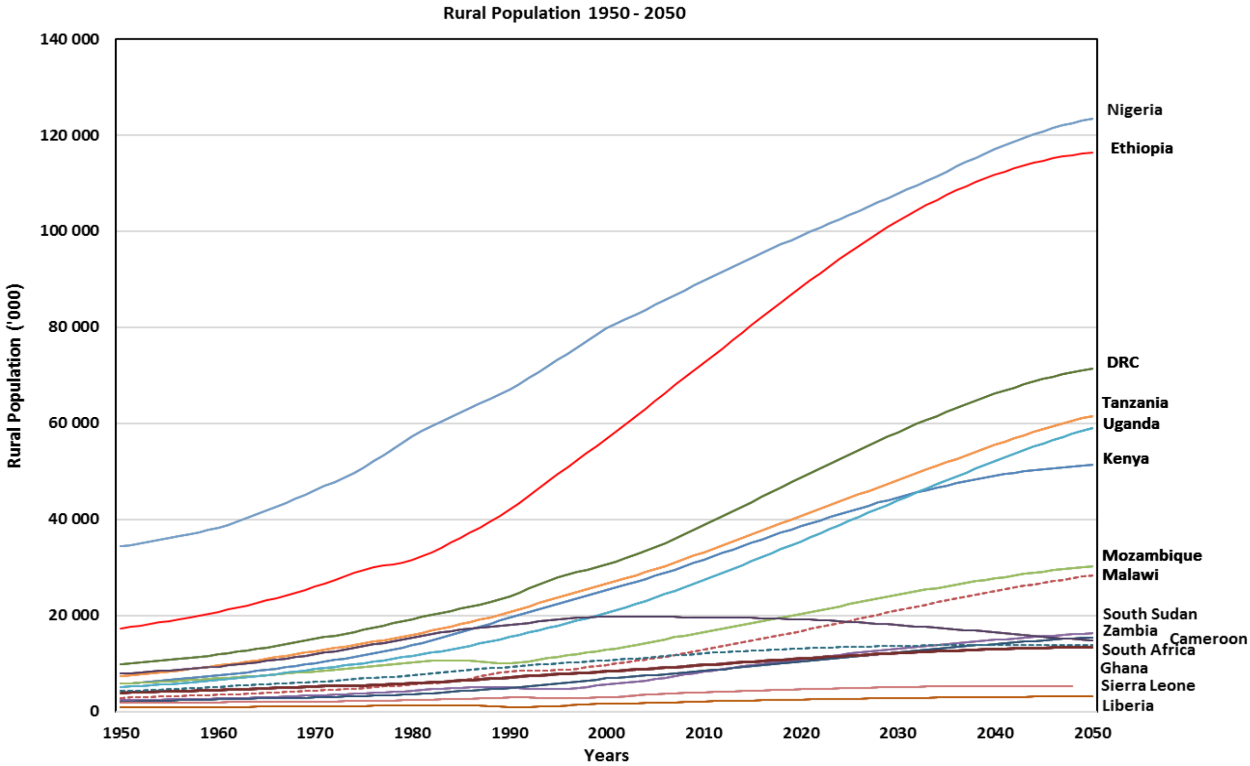

Figure 3: Rural population growth/decline for AfCAP countries and partner countries 1950 – 2050 (custom data acquired via UN ESA, 2018)

Table 2: Rural population growth in AfCAP countries and partner countries

AfCAP countries and partner countries	*2015 - 2050 Rural growth ('000)*	*Urban % 2015*	*Urban % 2050*
Nigeria	49 032	47.8	67.1
Ethiopia	37 375	19.5	37.6
Uganda	37 033	16.1	32.1
Democratic Republic of the Congo	20 456	42.5	60.4
United Republic of Tanzania	25 085	31.6	53.0
Kenya	19 766	25.6	43.9
Mozambique	12 105	32.2	49.1
Malawi	14 274	16.3	30.2
Zambia	9 278	40.9	58.3
South Sudan	6 490	18.8	33.9
Cameroon	3 924	54.4	70.0
South Africa	- 4 526	64.8	77.4
Ghana	1 075	54.0	70.5
Sierra Leone	607	39.9	57.2
Liberia	1 005	49.7	65.2

2.2 Projected Climate Change over Africa

To understand the potential impacts of climate change across the African continent the development and analysis of appropriate regional climate data is essential. Initiatives such as the Coordinated Regional Downscaling Experiment1 (CORDEX) has assisted in the development and coordination of downscaling of climate models to provide a set of high-resolution regional climate projections for the region (CSAG, 2018). Many publications have been produced reflecting this work and this has also contributed to the recent development of downscaled climate models specifically for this project. Simulations of the Coupled Model Inter comparison Project Phase 3 (CMIP3) and Assessment Report Four (AR4) of the Intergovernmental Panel on Climate Change (IPCC), all obtained for the A2 (low mitigation) emission scenario of the Special Report on Emission Scenarios (SRES), were downscaled to high resolution over Africa (Engelbrecht et al., 2015). It featured a number of variables including rainfall, temperature and drought using various percentiles. Examples of projected climate change over Africa are displayed in Figures 4 and 5. Figure 4 provides an example of the projected changes across a range of downscalings for maximum temperature (left) and extreme rainfall events (right). Similarly, Figure 5 illustrates changes in rainfall (left) and the average value of the Keetch-Byram drought index (right), for the period 2080-2100 relative to 1961-1990 under a low mitigation scenario.

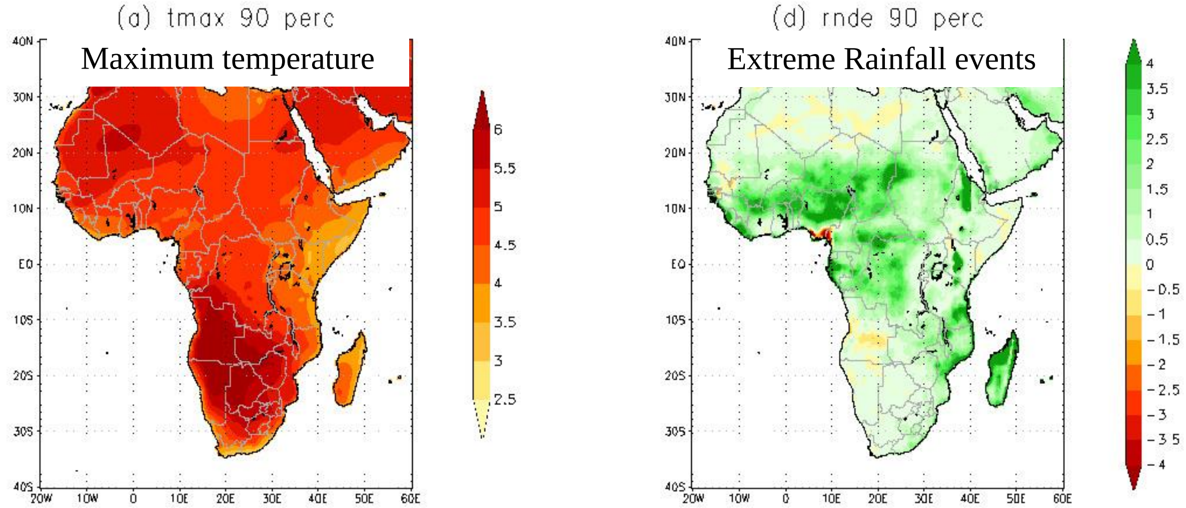

Figure 4: Example of projected changes in maximum temperature and extreme rainfall events (Engelbrecht et al, 2015)

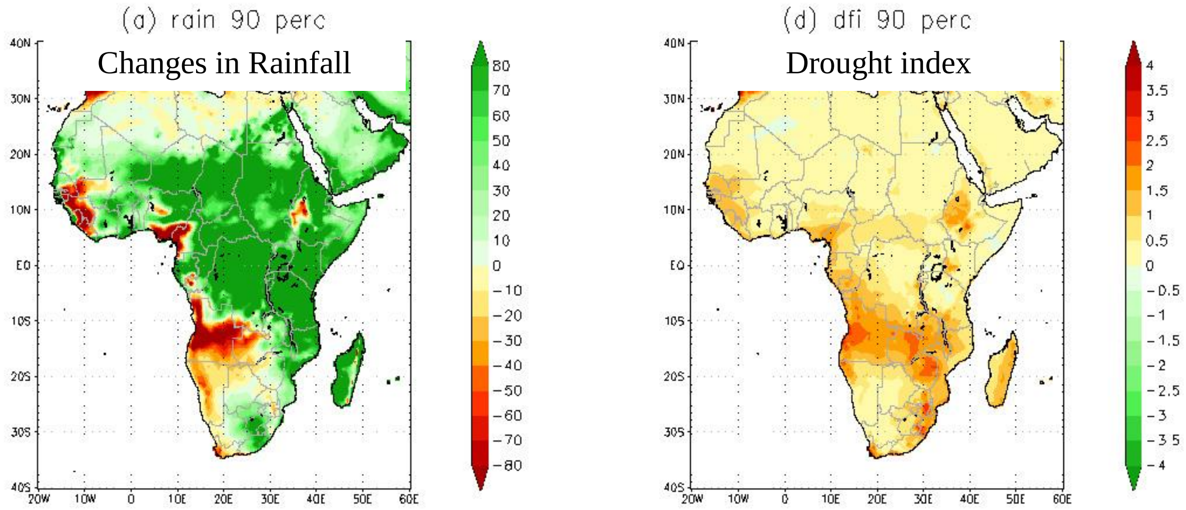

Figure 5: Examples of projected changes in rainfall and average value of the Keetch-Byram drought index (Engelbrecht et al, 2015)

African temperatures are projected to rise rapidly, faster than the global average temperature, and in the subtropics at a rate of about twice the global rate of temperature increase (James and Washington, 2013; Engelbrecht et al., 2015). Moreover, the southern African region and Mediterranean North Africa are likely to become generally drier under enhanced anthropogenic forcing (i.e. forcing due to human factors), whilst East Africa and most of tropical Africa are likely to become wetter (Christensen et al., 2007; Engelbrecht et al., 2009; James and Washington, 2013; Niang et al., 2014). More uncertainty surrounds the projected climate futures of West Africa and the Sahel, with some climate models projecting wetter conditions and equally credible models projecting drier conditions under climate change (e.g. Christensen et al., 2007; Niang et al., 2014).

Climate change is not expected to take place only through changes in average temperatures and rainfall patterns, but also through changes in the attributes of extreme weather events**.** For the southern African region, generally drier conditions and the more frequent occurrence of dry spells are likely over most of the interior (Christensen et al., 2007; Engelbrecht et al., 2009). Flooding events related to cut-off low weather systems are also projected to occur less frequently over South Africa (e.g. Engelbrecht et al., 2013). Tropical cyclone tracks are projected to shift northward, bringing more flood events to northern Mozambique and fewer to the Limpopo province in South Africa (Malherbe et al., 2013). Further to the north, over Tanzania and Kenya, more large-scale flood events may plausibly occur, should the future climate regime be characterised by a higher frequency of occurrence of strong El Niño events. Intense thunderstorms are likely to occur more frequently over tropical and subtropical Africa in a generally warmer climate (e.g. Engelbrecht et al., 2013). Uncertainty surrounds the climate futures of West Africa, the Sahel and the Horn of Africa, particularly within the context of how climate change may impact on the occurrence of mega-droughts over these regions (Lyon and DeWitt, 2012; Williams et al., 2012; Roehrig et al., 2013).

A survey of affected countries, followed by meetings with relevant government officials and workshops, has revealed similar experiences and problems to be addressed urgently:

- Road damage backlogs from climatic effects are increasing at an alarming rate and need appropriate guidance to address.
- Maintenance budgets are not adequate to deal effectively with climate effects requiring better *Return on Investment* and help with a *Do Nothing/Minimal* approach.
- Appropriate new policies and strategies need to be embedded in plans, programmes and projects.
- Knowledge and capacity on climate adaptation need strengthening in Roads/Transport MDAs in areas such as policy, planning monitoring and evaluation, standards development and asset management.
- Relevant climate-related data needs to be collected to support a new approach.
- There is a need for more effective engagement with development partners, with evidence to support funding applications.

More information on climate change information is reflected in the **Climate Risk and Vulnerability Assessment Guidelines.**

2.3 Main effects of climate change

Flooding is one of the extreme climate events expected to increase over sub-Saharan Africa (Serdeczny, et al., 2017). This is due to more frequent and more intense extreme events that cause damage or total destruction of roads and associated structures. Another common problem is land movement that affects natural slopes adjacent to roads, as well as cuts and embankments that comprise part of the road development. These problems are generally exacerbated by factors such as failure to

- take into account extreme conditions and signs indicating impending problems (and to take appropriate action)
- maintain the infrastructure adequately

- have funding available to implement timely preventative measures
- manage land use adjacent to roads which change can affect surface runoff and destabilise sloped areas along roads initiating landslides (Hearn, 2015).

The following sections briefly elaborate on each of these factors.

2.3.1 Failure to act

Not taking action to address the risks associated with extreme climate events stems from four causes:

- Lack of knowledge: Not familiar with or unable to understand the form or 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

Many governments on the African continent currently lack knowledge and understanding of the scale of the problem. Even where there is a basic understanding, there is often a failure to act because *adequate policies and strategies are not in place*. Failure to act is likely to result in increased costs related to dealing with disruption, loss of access, rehabilitation and socio-economic development. Shocks from unexpected extreme climate events also severely undermine community and business resilience, and harm the development gains made in such regions.

2.3.2 Poor maintenance

Historically, road asset maintenance has been sporadic and inadequate resulting in deteriorating assets. Records, management systems, supervision, monitoring and quality control have been weak or outdated. Problems have been exacerbated by some reluctance of development partners to set up maintenance funds within their new build or rehabilitation programmes. Consequently, significant maintenance backlogs are commonplace across the continent (Mostafa, 2018; Gwilliam et al., 2008).

2.3.3 'Low-cost' scenario

Capital and maintenance budgets are often insufficient, even when relatively well-managed Road Funds have been established. Poor prioritisation, through inadequate data and management systems, has often led to wasteful use of funds (Donnges et al., 2007).

In recent years, an increase in extreme weather and unpredictable rainy seasons has created unprecedented backlogs of maintenance and rehabilitation (Schweikert et al., 2014). Emergency funds are often woefully inadequate to address the increasing scale of damage due to climatic conditions. The situation is often exacerbated when cash flows are suspended and budgeted funds do not materialise. In the worst cases, backlogs cannot be addressed and maintenance programmes – except for routine maintenance – are suspended.

Based on consultations held with national stakeholders and responses to a mailed questionnaire (Verhaeghe et al., 2017), there is clear evidence that the lack of funds and inadequate budgets (to deal with the effects of climate change) affects all AfCAP partner countries, resulting in substantially underfunded maintenance, capital works and associated programmes. In many countries, only routine maintenance is carried out, unless Development Partner funding is available.

Managing access to road infrastructure for the rural population is particularly challenging in these circumstances, and is often referred to as a *No-Adapt* or *Do-nothing* scenario. In these circumstances specific actions and plans can be undertaken to reduce the impact of climate events and manage access through a planned programme of information management, early warning systems, community self-help programmes, emergency planning and stakeholder collaboration. Specific guidance for these circumstances is set out in *Adaptation Management with Inadequate Budgets Scenario* in Section 2.4.4 and throughout Section 3.

2.4 Drivers for change

Effects from changing and more extreme climate events are nowadays commonplace in many African countries. Although multisector policies and strategies on climate change are being introduced in many countries, those specific to the roads and related infrastructure sector are often lacking. The relevant policies, strategies and plans need to be modified to change the way in which climate change is addressed.

It is essential that the necessary views on and understanding of climate change are modified at the highest levels. Climate change considerations should be incorporated into government goals and policies, and could be general statements concerning adequate attention to potential issues, or statements targeted at specific types of vulnerabilities (e.g. sea-level rise). In countries where physical movement is still critical, roads are lifelines and their continued operation is essential to sustain livelihoods (Moretti, et al., 2018). According to (Lohesha, 2018) they are a critically enabling condition for improvement of living conditions and quality of life in rural areas.

2.4.1 Policy and plans

Government and MDA policies on climate adaptation for road and transport are virtually absent. Where present, roads are usually represented as a subset of all infrastructure, including energy and water supply, but it is more common for adaptation policies to be multi-sectoral and to cover agriculture, energy, forestry etc. Development partners, in particular the World Bank, are now recognising the importance of establishing specific policies and strategies for the road sector. Policy development is usually an integral part of strategic planning, programming, implementation and feedback. Policy sets the scope and content of strategic planning for programmes and plans which, when implemented, would be expected to create more sustainable rural access. Monitoring and evaluation will provide evidence and experience that can be fed back to modify or improve policy.

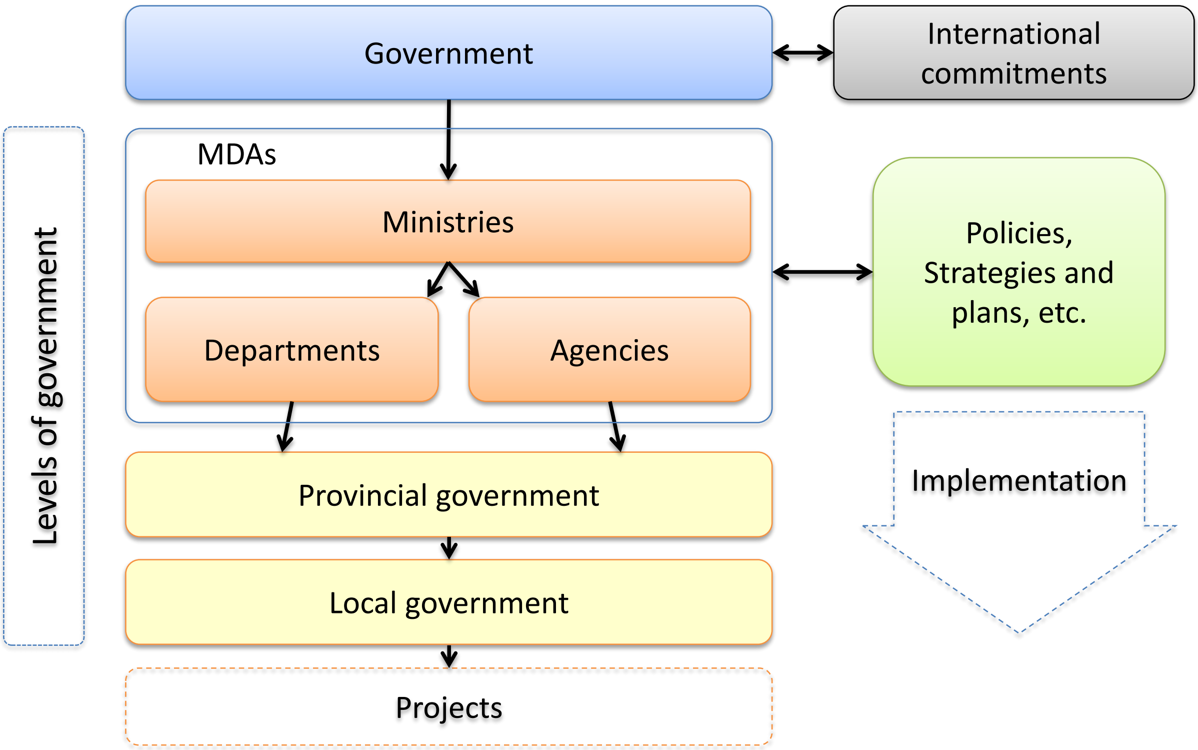

Figure 6: Generalised government structure with policy links

Integrating adaptation at policy and planning levels helps to clearly recognise climate risks and the need for adjustments to relevant national policies. Incorporating climate change into policies at this level means that it cascades into sector plans and other levels of decision making. Guidance intended to strengthen cross-sector cooperation between ministries is essential, as multiple institutions often deal with the climate change data aspects.

Recommended actions

The following actions are suggested to accommodate or improve climate adaptation:

- Review Government Policy
- Review Environmental Policy
- Review 20-, 10- and 5-year development plans
- Inspect strategies of MDAs
- Augment sectorial goals, objectives and strategies
- Foster cross-sectorial cooperation through engagements/agreements and multidisciplinary management
- Modify the scope of national climate change committees to include or enhance transport sector involvement
- Align implementation programmes in accordance with the above

2.4.2 Policy options for climate adaptation

Policies and plans should be adaptive and robust, and steer the incorporation of climate change into areas such as spatial planning, long-term improvement plans, facility designs, maintenance practices, operations, and emergency response plans.

Effective adaptation and mitigation activities are still lacking. This is due to poor coordination between sectors and limited capacity for mainstreaming, and the lack of the incorporation of climate adaptation in planning and budgeting, despite the widespread recognition of adaptation as an important issue among public, private and civil society actors. Instead, independent actions have been sporadic and ineffective, despite the inclusion of adaptation and mitigation policies and strategies in the environmental sections of central and district-level government.

The application of a climate lens is recommended at the national or sector level (OECD, 2009) to examine the following:

- Extent to which the policy, strategy, regulation, or plan under consideration could be vulnerable to risks arising from climate variability and change
- Extent to which climate change risks have been taken into consideration in the formulation of programmes
- Extent to which the policy, strategy, regulation, or plan could lead to increased vulnerability or maladaptation or, conversely, to missing important opportunities arising from climate change
- Pre-existing policies, strategies, regulations, or plans to be revised, as well as what amendments might be warranted to address climate risks and opportunities

A first quick application of the climate lens should enable a policy maker to decide whether a policy, plan or programme is at risk from climate change. If deemed to be at risk, further work is required to identify the extent of the risk, assess climate change impacts and adaptation responses in more detail, and identify possible recommendations and downstream actions.

Recommended policy option actions for adapting the transport sector to climate change, developed by the Bipartisan Policy Centre (BPC, 2010) are shown in Table 3. It describes the research/policy objectives and sets out appropriate policy responses. The policy options cover the full spectrum of planning, asset management, institutional changes, standards/regulations and performance measures.

Table 3: Policy options for adapting the transport sector to climate change (BPC, 2010)

Research/Policy Overview	Policy Description	Possible responsible institution(s)
Develop appropriate model outputs	Integrate climate data and projections, and more information about the likelihood and extent of extreme events, into transport planning.	Environmental Meteorology and Roads/Transport MDAs
Identify inventory assets	Make an inventory of transport infrastructure and locations that are vulnerable to climate impacts.	Roads/Transport MDAs
Identify secondary impacts	Conduct research on demographic/socio-economic responses to climate change and land use interactions, and how these responses affect the transport sector.	Planning-, Economic development- and Roads/Transport MDAs, Academic Institutions.
Support decision making	Provide modelling and adaptation planning tools to local governments to help identify vulnerabilities.	Meteorology Department
Facilitate coordination and collaboration	Facilitate and support cross-disciplinary coordination and collaboration among the public sector, private sector and local stakeholders to assess impacts, vulnerabilities, and adaptation options.	Climate research coordinating committee
Plan for emergency preparedness	Develop climate change strategies to integrate emergency responses into transport infrastructure design and operations.	Disaster Management Agency, Transport Ministry
Expand planning timeframes	Assist transport agencies to incorporate the effects of longer-term climate change into their planning processes.	Meteorology MDA
Refine risk analysis tools	Planners/engineers require support to develop and use probabilistic techniques in risk analysis tools to address uncertainties that are inherent in projections of climate phenomena.	Roads/Transport and Planning MDAs
Consider land use	Work with appropriate agencies to influence land use decisions and avoid inappropriate development in high-risk areas.	MDAs dealing with Land use planning
Develop risk assessment and adaptive management approach	Adopt an iterative risk management approach to provide transport decision makers a more robust picture of the risks to various components of the transport network.	Roads/Transport MDAs
Develop new design standards	Develop new design standards and codes to incorporate projected climate condition changes.	Roads/Transport MDAs
Update regulations	Require climate change adaptation screening in environmental impact assessments.	Roads/Transport MDAs
Make institutional changes	Make institutional changes to facilitate the integration of climate change impacts into the decision-making process for transportation planning and investment.	Roads/Transport MDAs
Assess costs and benefits	Provide guidance to identify opportunities for adaptation and to assess cost estimates and benefits for adaptation initiatives and programmes.	Roads/Transport MDAs

Research/Policy Overview	Policy Description	Possible responsible institution(s)
Develop performance measures	Develop performance measures to inform prioritisation and decision making on adaptation approaches and projects.	Roads/Transport MDAs

Where relevant policies are absent or restricted, they should be developed or augmented to cover climate adaptation in its broadest sense. Where an absence of adaptation policies, plans and programmes, and a lack of funding, cause severe constraints to the management of road infrastructure, a strategy for a 'Low-cost' scenario should be developed. The term 'Do Nothing' is normally used to signify little or no designated budgets or funds to deal with adaptation relating to vulnerability threats, existing damage backlogs or maintenance issues relating to road assets – thus limited action is taken. In such a scenario, a proactive management strategy should be developed to minimise disruption to rural access and to socio-economic development.

2.4.3 Translating policies into strategies and plans

At a strategic level, it is preferable to develop a national climate threat, vulnerability and adaptation strategy that would support the national climate policies. The results of the strategy should inform the next steps through the identification of specific vulnerabilities and locations where more resilient infrastructure is needed. It should consider the prioritisation process and its application to the road network at regional and district levels. Greater resolution may be required, depending on the threat and risks involved, and may influence future planning and development decisions. Finally, detailed assessments should be carried out at corridor or project level and strategies should be refined further, while consideration is given to budget implications and planning requirements.

Spatial Data Infrastructure (SDIs) is lacking in Africa and hence data harvesting/collection is more difficult and requires cross-collaboration between departments. Collaboration between ministries and departments is necessary to share knowledge and data when these studies are carried out. For example, the risk assessments require data from the meteorological office, roads authorities and disaster management departments.

Figure 7 demonstrates the continuous process of establishing policies, implementing them, evaluating their success, and finally, providing feedback for policy formulation.

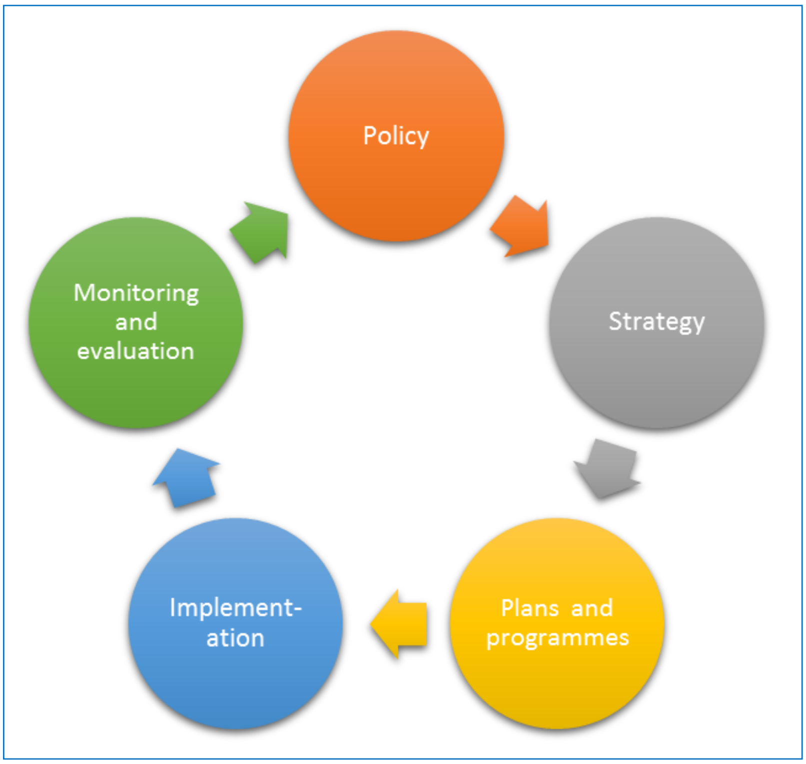

Figure 7: Processes to set, implement and update policies and strategies

Climatic factors have a direct impact on the condition of infrastructure as well as on operations and maintenance. Once the significance of these implications has been assessed, adaptation strategies can be developed to respond to them (see Figure 8). The responses should in turn affect the condition and resilience of the infrastructure, as well as the operations and maintenance requirements.

Through an adaptive approach, asset managers can evaluate the effect of adaptation strategies on system performance and tailor future adaptation actions. The aim of these actions is to further improve performance and enhance the resilience of the road network as funding becomes available. By taking pro-active measures, the most vulnerable infrastructure can be protected, thereby reducing the risk of system failure and the consequent harmful impact on human life and socio-economic activity.

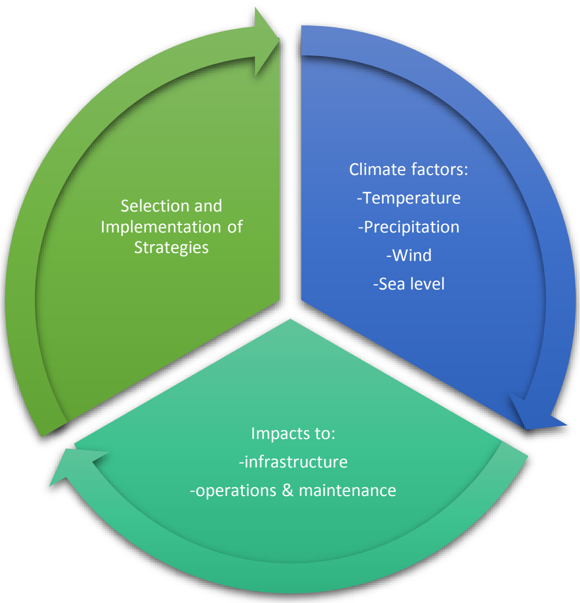

Figure 8: Climate driver impacts resulting in a need for adaptation strategies

Decisions pertaining to priority areas, alignment, land zoning, spatial planning, technology, and implementation plans are also generally made at policy and sector planning levels (ADB, 2011). Many of the examples of international adaptation strategies rely on the participation of multiple partners such as ministries of infrastructure and ministries of environment, which are more readily established if set at the policy level. Examples include the EU Commission report on the EU adaptation strategy (2013), the Australian National Climate Resilience and Adaptation Strategy (2015) and the Irish National Adaptation Framework (Department of Communications, Climate Action and Environment, 2018)

Information Box 1

Infrastructure assets and networks are capital intensive, long lived and interdependent across sectors. Decisions made now about the location, design and operation of these assets would determine their longer-term resilience to the effects of climate change. Strengthening resilience in this area is an essential component of climate adaptation, particularly since adequate and reliable infrastructure underpins growth. Taking climate resilience into account can protect investment returns, support business continuity and meet regulatory requirements. As such, infrastructure owners, operators and investors have an incentive to manage these risks, but a range of barriers may prevent them from doing so. These barriers include a lack of awareness or information, short-termism and misaligned regulatory incentives.

Four priority actions by national governments could support infrastructure resilience (OECD, 2009):

1. Ensure through capacity development that state-owned utilities, professional associations and regulators have or develop sufficient capacity to use climate projections and facilitate partnerships between sectors to better understand and address infrastructure interdependencies.
2. Account for climate risks when making public sector investments. Review the allocation of liabilities and investment responsibilities between the public and the private sector in Public Private Partnerships (PPPs) in view of climate change.
3. Align spatial planning policies, national and international technical standards, as well as economic policies and regulation in support of infrastructure resilience. Governments may want to ensure that international, national and local approaches are aligned in order to facilitate private sector adaptation.
4. Raise the profile of climate risk disclosure by encouraging participation in voluntary initiatives, supporting the development of common approaches at the international level, and using information gained from risk disclosures when planning climate adaptation at the national level.

Recommended actions

- Build awareness and capacity to facilitate relevant partnerships.
- Incorporate adaptation considerations into, for example, transport master plans. This is expected further secure the likelihood of meeting transport-related objectives and may also identify new priorities.
- Align spatial planning policies, national and international technical standards, and economic policies and regulations in support of infrastructure resilience.
- Gather policy-driven information or establish the explicit link between pilot project and policy mainstreaming. Adaptation strategies are tested and evaluated in the context of a given policy sphere and successful measures are fed back into the given policy. This integration can help improve the policy's general direction and ensure the achievement of its objectives.
- Integrate adaptation strategies into local comprehensive plans.
- Constrain locations of high-risk infrastructure.

Information Box 2

The Organisation for Economic Co-operation and Development (OECD, 2009) identifies the national and sector levels as policy entry points that may be useful for adaptation mainstreaming. National policies and plans include national visions, poverty reduction strategies, multiyear development plans, and national budgets. Sector development plans, such as transport master plans and their budgets, often flow from national plans and policies. Projects support sector plans and in some cases also national plans, particularly those that are cross-sector, regional, and of extremely high priority. Therefore, influencing these overarching frameworks can affect which projects are prioritised and the criteria they must meet in order to be financed.

Implementation of an adaptation strategy will require sufficient trained resources to implement action plans and programmes.

Recommended actions

- Assign sufficient resources to adaptation activities, to provide the capacity for implementing a phased and consistent approach towards addressing climate change risks.
- Develop a programme of training and piloting of the Adaptation Strategy for technical and operational specialists.
- Agree for programmes of vulnerabilities to be progressed to options analysis and action plan development.
- Initiate a 'quick-wins' programme that leads to the early implementation of adaptation actions where these are straightforward, low cost and their benefits are clear.

2.4.4 Adaptation management in cases of poor or inadequate budget scenarios (also referred to as the 'Do Nothing' or 'Minimal' approach)

Adaptation policies and strategies have to be developed to address the needs of vulnerable communities and budget constraints that may impact on specific areas or activities. The strategy should be directed at those areas or regions where there is evidence of adverse effects and where vulnerability assessment identified the greatest risks to assets, businesses and communities. The strategy should comprise the following components as a minimum to allow maximum active management of the network and help to communities and markets:

- **Preferred serviceability and accessibility criteria:** This is the baseline against which all options can be gauged. It conforms with agreed strategies and management targets relating to serviceability and accessibility.
- **Key focal points requiring normal and emergency access:** These relate typically to medical, educational, welfare, key supply, water supply, and power supply type facilities. Ideally, they should be identified through a GIS system and incorporated into an asset management system.
- **Early warning:** This links local monitoring with real-time regional meteorological information to provide an early warning management system that can be translated into a series of actions by coordinated stakeholders. Where early warning systems do not exist these should be established and possibly linked to disaster response functions. This however is also dependant on costs, as well as technical and skills requirements.
- **Emergency response:** This deals with immediate and threatened access to communities and facilities.
- **Vulnerable communities:** Collaboration is needed with and among communities to help maintain access. Through a consultation and information-sharing programme, a network of individuals and communities should be established to provide self-support and actions to help maintain

accessibility throughout and after intense weather periods. Work plans and assistance programmes should be developed to assist those who are particularly vulnerable.

- **Isolated communities:** Contingency plans are to be developed and temporary measures put in place to establish minimum access, possibly through diversions. Such plans may be temporary or permanent and should prioritise the most vulnerable socio-economic groups.
- **Key A-to-B routes with active diversions:** These are to be deployed as part of a communication campaign. Temporary diversions should be developed and managed with active communication channels to deal with changing daily and weekly dynamics.
- **Routes closed for short/long periods and permanently:** Contingency plans should be developed. Non-key routes might be left closed for temporary or extended periods during adverse weather periods.

The strategy for this scenario should be a balance between active and reactive management that involves all stakeholders and communities. It requires a **management plan, communication plan** and an **implementation plan** with associated actions and responsibilities. These plans then form the basis of a **cooperative communication and action campaign**.

Recommended actions

Maintain a safe and serviceable network in the following ways:

- Develop proactive strategy and programmes to identify where options can be applied in a strategic way (Roads planning and asset management departments)
- Develop contingency plans (Planning and disaster management departments)
- Ensure the delineation of alternative routes (Planning and disaster management departments)
- Establish temporary measures (Planning and disaster management departments)
- Monitor climate changes and their effects (Planning department collaborating with climate institutions)
- Address the implications and consequences of doing little or nothing (Transport planning, asset management and transport policy departments)

Besides protecting the value of assets, road user safety should also feature as a prominent issue in any climate change risk assessment and response strategy. Similarly, the protection of road workers should be looked after, particularly during extreme weather events where they may be tasked to clear debris, redirect traffic or institute emergency repairs.

A continuous programme of monitoring and evaluation by the Roads/Transport MDA (in collaboration with disaster response institutions) is needed in those areas where no physical interventions take place, so that all unexpected circumstances can be dealt with, also by emergency response. Climate change and its effects should be monitored and evaluated to update the management plans.

3 Change Management

Change management has the potential for making significant steps towards creating resilience to cope with likely climate effects in a cost-effective way. It covers policy, planning, implementation, stakeholder engagements and asset management, and involves the formulation of strategies and programmes for improvement. Change management is important for implementing institutions as climate change adaptation is likely to result in changes to designs, guidelines, project planning and execution, asset management systems, etc. It can also lead to the need to create a new unit or department to address climate change issues within the institution. It may therefore change the institutional tradition of responding to climate events to an approach in which long term measures to reduce climate risks and secure livelihoods are implemented (Wilby et al., 2011). Change management also pays particular attention to the management of measures that could be taken in a scenario where budgets are poor, inadequate or absent. Change management options are often referred to as *non-engineering options* and consist of a range of policy and management improvements. Associated activities to address the adaptation of road infrastructure and asset management tend to be more strategic and organisational in their nature than engineering options and **are generally applied in conjunction with engineering options**.

3.1 Integrated approach

By implementing an integrated approach, stakeholders can anticipate and mitigate negative impacts in a more effective way. This section features a wide range of issues that relate to change management and strategies to deal with climate effects. Due to the multi-dimensional aspects of climate change, some items are more closely related to infrastructure, whilst other deal with related domains such as environmental management and early warning.

3.1.1 Identification and mobilisation of stakeholder and expertise involvement

Relevant stakeholders including Ministries, Departments, Agencies/Authorities, institutions and research organisations should be consulted. Furthermore, specific engagement of local communities, non-government organisations, and small-to-large businesses operating in the sector would be important for conducting a vulnerability assessment and for engaging in the selection of the most effective adaptation strategies.

Recommended action

Consult with relevant stakeholders dealing with climate change research and data such as the following:

- Central government agencies that have a vested interest in road infrastructure planning and development
- National planning department
- National transport sector stakeholders, including roads and transport MDAs
- Investors/funders of road asset projects
- Other relevant government ministries/ departments (e.g. agriculture, environment, science and relevant technology sectors)
- Climate change committees
- Multi-sectoral committees
- Institutes dealing with meteorology/hydrology (e.g. water resources, hydrology and flood control)
- Emergency services and/or the national department dealing with disaster management
- Relevant businesses and NGOs
- Local-level stakeholders directly affected by the activities of the project (i.e. organisations involved in road construction and/or maintenance; community representatives; local

government representatives who report to various district and central government departments and agencies; affected village groups)
- District representative of central government agencies and departments with a vested interest in road infrastructure planning and development (e.g. road and transport, disaster management, environment, agriculture, social and economic development, health, education)
- District road engineers

In addition to engineering support, and depending on the nature of the project, it may be necessary to consult other technical experts including hydrologists, economists, climate specialists and/or social scientists.

Remarks on dealing with a poor, inadequate or absent budget scenario

For project planning, management and coordination purposes, the following stakeholders should also be engaged to identify and implement remedial actions for dealing with the consequences of potential road closures caused by (extreme) weather events:

- Local communities and businesses
- Local schools, clinics and hospitals
- Farmers and traders
- Charitable organisations
- NGOs
- Development partners

3.1.2 Improved network and programme management to anticipate and mitigate impacts

Climate changes necessitate the introduction of different design criteria, asset management policies, maintenance cycles, operational strategies, and therefore also different funding requirements and models.

Recommended actions

Enable the more effective management of the road network by doing the following:

- Improve investment decision tools (e.g. risk assessment, cost-benefit analysis, return on investment) and decision rules for prioritisation of adaptation options and investments.
- Establish and implement adaptation plans to provide primary and alternative access routings, from a transportation perspective, to mitigate impacts.
- Establish emergency routings that have climate resilience.

Information Box 3

Examples of actions taken by UK Highways England to align strategies (Highways Agency, 2008):

- Alignment of the road authority’s responsibilities and corporate objectives
- A focus on the activities of the road authority, and how they need to change in response to a changing climate
- Identification of priority areas within institution for action
- Integration, where possible, with the ways in which the road authority fulfils its current responsibilities
- Establishment of clear responsibilities for developing and implementing adaptation actions in specific areas of activity, and for facilitating strategic oversight of progress and residual risk
- Some actions require flexibility to enable the adaptation process to evolve and accommodate changing demands placed on the road authority, developments in climate science and the results of research and/or monitoring. Some of these items are new additions within road departments.

It might be prudent to appoint a **Climate Change Adaptation Programme Manager** within the Roads/Transport MDA, who should be responsible for overall management of the implementation of the Adaptation Strategy. His/her key responsibilities could include the following:

- Monitoring legislative and other policy developments
- Developing training materials for technical and operational specialists
- Monitoring developments and updating climate trends information
- Maintaining the vulnerabilities schedule
- Dissemination and communication of outcomes and decisions
- Agreeing an annual programme of work with asset managers for options analysis and the development of adaptation action plans
- Producing activity and progress reports

Remarks dealing with a poor, inadequate or absent budget scenario

For planning, management and coordination purposes, relevant plans should also include:

- Information on
  - routes that might have to be closed during extreme weather events or prolonged rainfall,
  - routes that should remain open,
  - how the open routes link together to ensure reliable access to key destinations.
- Contact points for vulnerable communities to receive help, advice and support.

3.1.3 Improved asset management resilience

Asset management and associated procedures is a key component to delivering more resilient infrastructure. Asset management systems are important elements in overall change management as it represents the link to decision and planning systems.

Recommended actions *(also indicating possible responsible entities)*

Improve the resilience of the network by doing the following:

- Catalogue the asset inventory (Asset Management Unit)
- Map (by using GIS) infrastructure assets in vulnerable areas, inventory assets that are susceptible to climate change impacts (GIS function in Roads/Transport MDA, else collaborate with appropriate institution(s))
- Collect elevation information as standard practice (GIS function in Roads/Transport MDA, else collaborate with appropriate institution(s))
- Use standard data collection systems between districts so that asset information can be compiled nationally (Asset Management Unit)
- Manage construction and operations to minimise the effects of seasonal weather extremes (Planning, Maintenance and Operation unit)
- Update operating procedures to take account of the impacts of climate change (e.g. update the procedure for working in high temperatures) (Planning Unit / Operations Unit)
- Incorporate procedures to augment operational management and particularly inadequate budget scenarios. Such procedures should cover:
  - Road weather programmes – with a means of sharing up-to-date information on the internet, via texting or mobile to a network of agreed contact points
  - Disaster preparedness planning – in collaboration both with institutions and with communities
  - Alternative transportation access – agreed with formal and informal transport suppliers
  - Evacuation planning – at all levels, from individuals, families, to whole communities with cross agreements between communities to help and support each other

- Feature road user safety as a prominent issue in any climate change risk assessment and response strategy.
- Manage the safe protection of road workers, particularly during extreme weather events where they may be tasked to clear debris, redirect traffic or institute emergency repairs (PIARC, 2012).

3.1.4 Maintenance planning and early warning

Weather variability and the short- and long-term effects of climate change could necessitate more frequent maintenance, rehabilitation and reconstruction of road infrastructure (e.g. access roads, geotechnical structures, bridges and drainage structures), as well as different design requirements – all of which could have an impact on the budgets of road authorities. Early warning systems could enable in-time preparation of emergency response actions, the monitoring of high risk roads (to prevent loss of live), and informing construction and maintenance sites of risks. These systems are normally present in a national disaster centre, however some roads departments also have disaster management functions to deal with departmental responses. Links to such early warning/disaster risk centres are essential for a roads department.

Recommended actions *(also indicating possible responsible entities)*

- Identify the most cost-effective adaptation options to design and construct assets that are more climate resilient and to ensure that (all-weather) rural accessibility can be sustained (Roads engineering unit)
- Develop and implement risk-reduction climate adaptation strategies and action plans (Policy unit)
- Perform periodic maintenance with a view to rectifying emerging problem areas (Maintenance department)
- Allocate funding for emergency repairs and for short- to long-term strengthening of infrastructure (In house funding function or links to a disaster fund established by government)

For affected infrastructure that is already in place, preparing emergency and maintenance contingency plans and budgets should enable quicker response for the most vulnerable areas. This reduces extended periods of road closures and other more serious consequences of disasters.

Condition assessment and performance modelling are expected to be improved by the following:

- Monitoring and identifying asset condition in conjunction with environmental conditions (e.g. temperature, precipitation, winds) to determine the degree and extent to which climate affects performance
- Incorporating risk appraisal into performance modelling and assessment
- Identifying high-risk areas and highly vulnerable assets
- Using smart technologies to monitor the condition of infrastructure assets
- Keeping records of maintenance activities, including specific location
- Keeping records of road closures due to, for instance, flooding

Recommended actions (Gallivan et al., 2009)

- Establish or enhance cross-ministerial committees for managing adaptation to climate change, including for transport.
- Strengthen departments of disaster risk management and meteorology to improve information based on which to make decisions.

- Introduce early warning and response systems for transport ministries to improve maintenance schedules and to respond quickly to post-disaster recovery needs.
- Promote low-risk adaptation strategies (such as cleaning drainage infrastructure, spot maintenance, and focussing maintenance and construction on high risk areas) that are expected to have development benefits regardless of the nature of climate changes that may take place. This is a useful approach where uncertainty is high regarding climate change and capital investments for large-scale infrastructural changes cannot be justified.
- Incorporate climate change adaptation into environmental impact assessments and strategic environmental assessment guidelines. This can take place specifically in the transport sector or, preferably, as part of the national standards. Road and transport ministries can test tools and adaptation approaches by applying strategic environmental assessments on climate change to their sector policies and plans.

For infrastructure that is already in place, increasing the maintenance contingency budgets in areas where climate change impacts are acute, would allow more intensive supervision and monitoring of the most vulnerable areas (ADB, 2011). This can reduce road closures and more serious consequences of disasters. Furthermore, maintenance management systems can include early warning systems to anticipate extreme events so that crews and contractors can be prepared for an upcoming high rainfall event and possible landslides. This should ensure that forced road closures are kept to a minimum. Alternatively, pre-emptive road closures may minimise losses of property and life. Financial resources are already insufficient to address day-to-day maintenance problems and emergency repairs caused by weather variability – much less to make investments on the basis of changes that may or may not occur years or even generations into the future. Here, however, the identification of areas of higher priorities for action could result in the more effective application of limited financial resources.

3.1.5 Actions following a disaster event

The following specific stages of data collection are recommended following a shock event (by Roads/Transport MDAs):

Stage 1: **Initial screening** to determine the functionality of the road network in terms of access and potential hazards. The items being recorded at this point may include the following:

- Evacuation routes/highways being blocked and/or over congested
- Road closures plus reasons for closures (broken/abandoned vehicles, other objects on the road or unpassable damage
- Bridge damage/closure
- Flooding as a result of an event or secondary flooding due to broken pipes
- Risk of secondary spills, leaking gas pipes or fallen power lines
- Pedestrians or people evacuating on foot

Stage 2: Detailed assessment or repair needs – this stage will involve a more detailed damage assessment of targeted infrastructure to determine the actual damage and repair or rebuilding requirements. It will also include assessing the feasibility of emergency repairs that may temporarily restore the functionality of the route, with more intensive restoration happening at a later stage.

Although the specific road or route functions may change over time, the road infrastructure remains one of the top critical infrastructures during the entire duration and in the direct aftermath of the disaster. Table 4 (Hallegatte et al., 2016) lists some of the priorities (effort and resources) following an event, along with the specific road network function for each of the priorities. Although access is in most cases the main function for the road network, being able to carry sufficient capacity (e.g. during evacuations) could also be important.

Table 4: Immediate priorities following a disaster

Priority	Objective	Priority	Road Network Function
High	Support immediate rescue Enable support from other areas	33% 17%	Access & capacity Access
Medium	Support lifelines Repair key infrastructure	15% 14%	Access Wider mobility
Low	Facilitate accessibility between communities Protect environment Protect private property Protect economy	7% 6% 4% 4%	Connectivity, access and capacity

Source: (Hallegatte et al., 2016)

Decision making following a disaster event is unique to each event and set of circumstances. Where funds are scarce or absent, actions and solutions are particularly challenging. Although it is believed that asset management processes could be of great value during these planning stages, certain considerations such as the following should be kept in mind (World Bank, 2017):

- **Planning in terms of distinct stages (response, recovery, and rebuild) following a disaster –** Each one of these stages may include a full asset management cycle, although the planning time horizon of the stages differs:
    - Response – planning for the next hours and days
    - Recovery – planning for weeks and months
    - Rebuild – planning for the long term, even longer than normal asset management cycles
- **Chaos** – Post-disaster reviews of major events (e.g. recurring destruction of embankments and structures in the Limpopo basin in the Gaza Province of Mozambique) often document the initial stages of the planning processes to be un-organised and fragmented. Having pre-event planning strategies in place assists bridging this stage quickly. Some of the pre-event planning strategies may include:
    - Where will the data be sourced from?
    - How to mobilise planning work forces?
    - Where are the most likely places where planning will take place?
    - How will the planning processes be managed?
- **Nature of the disaster –** The nature and specific damage following a disaster will inform the planning needs.
- **Mobilisation of workforce** – Getting workforces mobilised may pose a significant challenge after major events, as workers will also have their own families and properties to attend to.
- **Community involvement in decision making** – Disasters are often associated with significant tragic circumstances such as loss of life, destroyed properties and the displacement of large numbers of people. Obtaining community involvement in the decision making and actual rebuilding is vital. This priority brings a specific need to the planning process, how it is done and how it is communicated.
- **Voluntary sector, NGOs and charities –** Agreement with key organisations about what can be mobilised for different circumstances and how the chain of command will work.
- **Police, military and emergency services –** Agreement with key organisations about what can be mobilised for different circumstances and how the chain of command will work.

- **Build back better** – This concept ensures the best outcome for the community when decisions are made and financial aspects often become only one of the considerations. A main consideration during this stage is striking a balance between cost and future proofing.

3.1.6 Environmental management

Environmental Impact Assessments address the effects that roads have on the environment. Climate adaptation is the converse, with the environment affecting the road infrastructure. However, many of the issues and considerations overlap or can be harnessed for both.

Some biophysical drivers of vulnerability include poor land management, deforestation, slash and burn agriculture, monoculture cropping, slope instability, and geophysical instabilities. Some ecosystems, such as mountain ecosystems, are also inherently more sensitive to changes, while others (such as low-lying coastal areas and desert margins) are more exposed to climate changes and risks. Biophysical drivers that may exacerbate damages to roads and stream crossings are potentially numerous and may include the following:

- Deforestation and loss of land cover
- Anthropogenic coastal and riverbank erosion
- Over-extraction of groundwater for domestic, agricultural and/or industrial use
- Ecological degradation caused by unsustainable development

Using GIS, it is useful to map areas that are particularly vulnerable to a combination of local conditions and climate variability. This assessment can be conducted in the context of initial environmental and social assessments for a road transport project. The mapping can point out areas that are vulnerable because of their geographic and socio-economic characteristics:

- Areas that are sensitive due to topography (e.g. steep slopes), soil composition, geophysical instabilities or elevation (e.g. meters above sea level)
- Areas in the watershed that are exposed to climate-related hazards, including floods, landslides and droughts

There are a number of examples where the environment can be used to alleviate climate effects. Environmental buffers that moderate damage from floods, droughts and landslides include increased vegetative land cover and the preservation and conservation of mangroves, wetlands and forests – all of which help to regulate the hydrologic cycle. Other means of modifying the environmental hydrology and river basin management in the vicinity of rural roads include:

- Vegetative membranes for embankments or slopes that are unstable or at risk of erosion
- Vegetative pavement or channel lining
- Flow-deflecting plates or upstream vanes to modify flows
- Basins to collect silt and debris
- Plant and bush planting to prevent bank erosion
- Stream training and channel improvements to reduce unstable or unsteady flow
- Tetrapods (artificial concrete blocks)
- Check dams (installing sills or drop structures)

Adjustments can also be made to environmental management plans by selecting more drought- and heat-tolerant indigenous species during post-construction rehabilitation works or during maintenance works. Some of these responsibilities do not reside with the Roads/Transport MDA, and will require collaboration with other MDAs such as Environment, Forestry, Agriculture and Water.

An integrated system approach should be adopted. For example, ecosystem-based adaptation strategies should be designed and implemented to focus on environmental or green planning for project roads and to improve flood and drought management. Climate-change resilient trees can be planted along embankments of all project roads together with selected grass and biomaterials. This activity should take place after the roads have been paved, so as not to obstruct roadwork during the rainy season.

Other activities suggested for managing floods and droughts include the following:

- Restore the natural form and processes such as allowing streams and rivers to take natural courses.
- Use bioengineering and local plant species to prevent soil erosion.
- Allow unstable slopes to collapse and limit shoreline armouring.
- Restore shorelines.
- Create drainage ponds and ecological overflow systems.
- Conduct targeted removal of dikes.
- Drain wetlands.

Recommended actions

Roads/Transport MDAs should incorporate appropriate adaptation measures into their implementation plans:

- Introduce climate change vulnerability and adaptation considerations to criteria used for selecting projects for implementation and financing.
- Develop sector-specific and country-specific screening tools to identify projects at risk.
- Incorporate contingency budgets for specific adaptation interventions as the need arises.
- Adjust zoning regulations for transport infrastructure (for example, to avoid flood zones).
- Design flexible transport infrastructure that can accommodate incremental changes over time.
- Incorporate climate change indicators into budgeting frameworks to ensure accountability.

3.1.7 Hydrological management

Surface water hydrology characteristics and their management constitute a key component of adaptation management. A full understanding of quantities, direction, intensity and period of river catchment flows is fundamental to adaptation options and measures. Effects range from *immediate* (within and immediately adjacent to the road or structure), to *intermediate* (where flows and tributaries from immediate river catchments may affect the road assets), to *remote* catchments (that can be transregional and transnational in their geography).

Data management is essential to predict quantities and return periods for the study areas so that designs and maintenance regimes can be set out.

In addition, water body/river management practices and structures could affect the resilience of road assets. Controlled or uncontrolled water management practices should need to be taken into account when selecting design and maintenance approaches.

During periods of heavy rainfall, the presence of water may cause impassable conditions, splash and spray, limited visibility and increased discomfort. All of these could have an impact on safety. Generally, roads are designed to transport water as quickly as possible from the road surface to the road verges and drainage systems. High precipitation rates, especially in hilly areas can cause roads to have a thick surface water layer or even to be flooded to a certain extent, not only because the water cannot be transported away quickly enough, but also because water flows on to the road from the surrounding environment. In the latter case especially, not only water is transported, but also other materials such as mud, resulting in reduced pavement friction (PIARC 2012).

Recommended actions

- Co-operate on an inter-ministerial level for riverine and water body management, including flood management and emergency controls.
- Co-operate on an international level where major rivers cross more than one country.

3.1.8 Augmenting standards and design guides

Most current standards and national guides do not incorporate adaptation principles in any meaningful way. Investments in the transport sector are generally guided by a large number of design standards and regulations that in most cases are reflective of historical rather than future climate conditions. The revision of regulatory and design standards in the transport sector may significantly enhance the resilience of new transport sector investments to climate change. Ongoing dialogue with national transport sector stakeholders offers an opportunity to initiate such revision. In some instances, transport authorities (for example in Mozambique and Ghana) have initiated a review of standards and design guidelines to incorporate issues of climate adaptation.

The impact of using inappropriate designs and guidelines can be considerable, whether for new infrastructure development, rehabilitation, upgrading or maintenance of assets. Operational responses are often geared towards addressing short-term impacts of climate change, particularly recent damage of existing infrastructure. To make decisions about rehabilitating or retrofitting transportation facilities, especially those with long design lives, transport planners and engineers must also consider how climate change could affect these facilities in coming years. Adapting to climate change would require re-evaluation, development and regular updating of design standards that guide infrastructure design. In the interim, producing addendums/appendices to existing standards and design documents will greatly assist the immediate implementation of more appropriate approaches (ADB, 2018; Environmental Agency, 2016).

Updated design requirements, including technical standards and specifications, should provide additional resilience and reduce vulnerability. These updated requirements apply to designs for new structures or new roads, as well as to designs for maintenance, renewal and improvement works.

The full development of design standards is a time-consuming and systematic process that involves professional organisations in an extensive research and testing programme over a period of decades. Thus, once the standards are in place, engineers are reluctant to change them. As the effects of climate change result in more regular and abrupt impacts on road pavements, more regular re-evaluation and updating of design rules, standards and specifications for road pavements would be required. This would also require more intensive short- to medium-term research, as well as development and implementation efforts to develop and validate these new design rules, standards and specifications.

The suggested prioritisation of changes to standards is set out in Figure 9. In a survey of transport officials in Asia (Regmi et al., 2011), respondents were asked if they agreed with 14 statements regarding changes in design standards and practices. A larger percentage of respondents answered "yes" to statements pertaining to addressing changes in precipitation and flood damages, thus emphasising the importance of drainage management and protection.

Recommended actions *(also indicating possible responsible entities*)

- Inspect all existing standards, guides, manuals and similar publications/documents to determine whether climate threats and associated adaptation are adequately covered (Roads/Transport MDAs with assistance from specialists dealing with climate change)
- Determine which documents are being updated (or are soon to be updated) and initiate actions to incorporate adaptation in their Terms of Reference (Roads/Transport MDAs)
- For those with no immediate plans to update, decide whether to bring forward the update or whether to produce some form of augmentation (Roads/Transport MDAs)
- Form a multidisciplinary/multisector working group to scope out and deliver the necessary adaptation augmentation requirements based on the prioritisation set out above (Roads/Transport MDAs, but could also involve Development Partners)

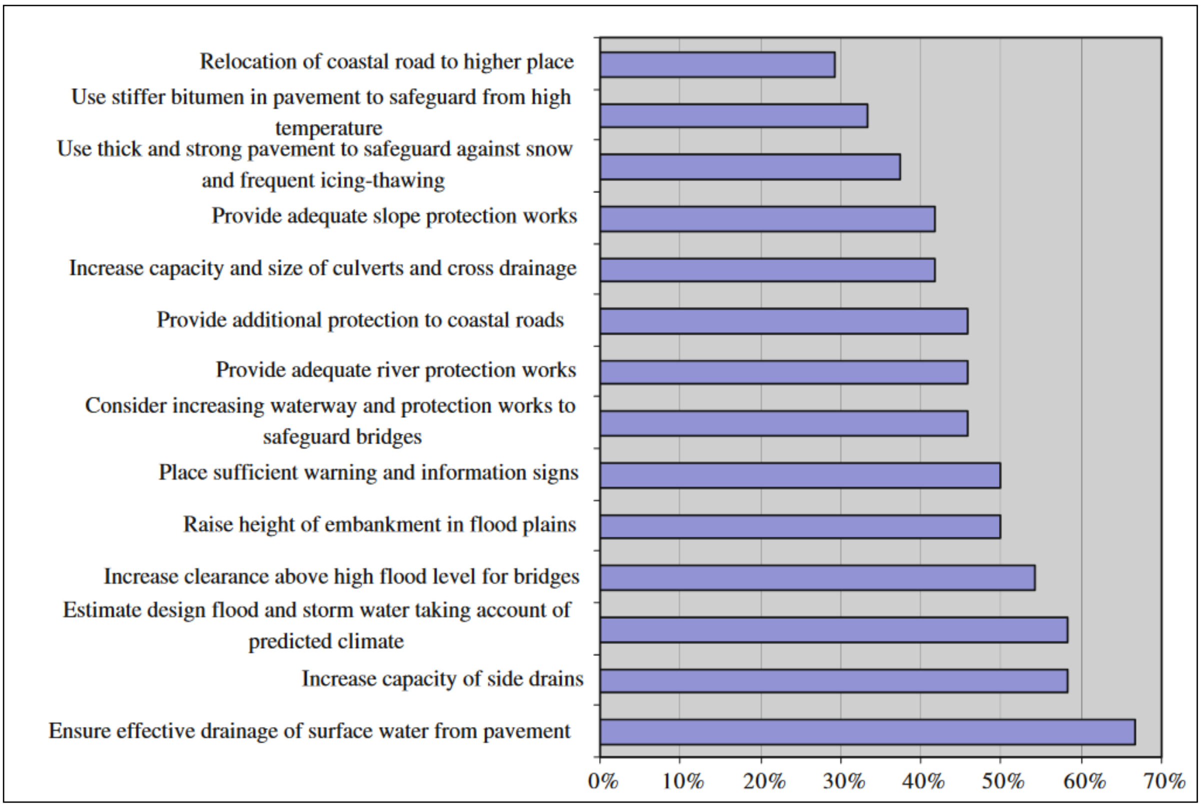

Figure 9: Prioritisation of changes to design standards and proposed changes to management

Source: (Regmi et al., 2011)

3.1.9 Road safety

A current constraint is that climate change impact assessments do not sufficiently consider road safety (Hambley, 2013). Road user safety should feature prominently in any climate change risk assessment process. Risks that could be attributed directly to climate change effects include the following (PIARC, 2012):

- Aquaplaning of vehicles on water accumulated on the road surface and in ruts, due to instability from potholes or subsidence
- Skidding of vehicles caused by a lack of friction during or shortly after intense precipitation events, or as a result of bleeding of bituminous road surfaces caused by high temperatures
- Loss of control over a vehicle as a result of severe wind conditions, high currents during flooding, etc.
- Reduction in visibility during intense precipitation events and sand storms
- Impairment as a result of flooding, landslides, mud flows, etc.

Recommended actions *(also indicating possible responsible entities)*

- Conduct risk assessments as part of normal network management. This activity should be augmented to cover additional risks due to adverse weather or adaptation activities (Roads/Transport MDAs)
- Carry out road safety audits for new construction programmes and broaden these audits to cover the effects of adverse weather and the associated adaptation (Roads/Transport MDAs, with assistance from road safety specialists)

Most of these **direct** risks can be dealt with proactively by improving the functional and structural characteristics of the road pavement and the road environment. Other more serious effects are expected to require emergency responses, such as network restrictions or even road closures, to maintain safety.

In addition to the direct risks, there are **indirect** risks that also need to be considered, such as the inability to access disaster areas and emergency facilities as a consequence of road closures. Indirect risks would require a different set of emergency responses, such as the provision of alternative access.

It is expected that, as a consequence of extreme climate effects, road pavements and other infrastructure may require more regular maintenance than is currently the norm. This may require road workers to work on the network more often and also during extreme climatic events; hence the need to include the safety of road workers in the risk assessment process.

3.1.10 Research

The collection of data, piloting of new approaches and evaluation of outcomes provide evidence to underpin research outputs and to inform the scope of future research. In this case, the main purposes of research are to

- build greater certainty into climate change projections;
- provide better understanding of the likelihood and consequences of a risk for the network;
- find ways to cope with climate change (e.g. determining cost-effective and sustainable adaptation options with a reasonable level of confidence, and providing substantiated arguments for implementing changes to norms and standards); and
- reduce uncertainty in climate change adaptation.

Demonstrations and trials linked to monitoring and evaluation programmes are valuable ways of assessing the products of research and of educating stakeholders on methods and outcomes.

Recommended actions *(also indicating possible responsible entities)*

- Engage with the National Research Foundation and tertiary education institutions or Government archives on relevant research undertaken (Roads/Transport MDAs)
- Coordinate or link planned climate adaptation research programmes to build competence and expand knowledge (Roads/Transport MDAs in collaboration with other Climate Change institutions)
- Collect experience and case studies for publication and dissemination (Climate Change Coordinating body)

3.2 Managing the adaptation process

Once the process, sequence and necessary adaptations have been determined from the initial assessments and prioritisation inputs, their implementation needs to be carefully managed. This requires close supervision by the design engineer/team to ensure that the assumptions made (where no information was available) are valid on site, that the measures have been correctly implemented and that the installation of the measures meets the required standards and fulfils the design requirements. For example, if a mortared stone-pitched facing is specified to obviate erosion of an embankment, the work must be such that the final product has no apertures or cracks that may allow water to access the material being protected. To ensure that this is achieved, some signoff process could apply as part of Monitoring and Evaluation. Additionally such implementations could be part of a series or learning sites.

3.2.1 Adaptation options in the roads sector

The types of actions that can be taken to reduce vulnerability include avoiding, withstanding, and/or taking advantage of climate variability and impacts include:

- Avoiding areas that are projected to have a higher risk of potentially significant climate impacts plays an important role in planning decisions.
- If such locations cannot be avoided, steps need to be taken to ensure that the road infrastructure can withstand the projected changes. For example, the potential for increased flooding might be a reason for increasing bridge elevations beyond what historic data might suggest. It should, however, be noted that most of the problems experienced are related to existing infrastructure that cannot easily be relocated.
- The result of adaptive action either decreases a system's vulnerability to changed conditions or increases its resilience in case of negative impacts. For example, increased temperatures could cause pavements on the highway system to fail sooner than anticipated. Using different materials or different approaches that recognise this vulnerability can lead to pavements that should survive expected higher temperatures better.
- With respect to resilience, operational improvements could be made to enhance detour routes around flood-prone areas. Another example is well-designed emergency response plans that can increase resilience by quickly providing information and travel alternatives when roads are closed or facilitating the rapid restoration of damaged structures. By increasing system resilience, the road network as a whole should be expected to still function, even though a particular facility may be disrupted.

The following are the primary engineering options:

- ***Subsurface conditions*** – The stability of any type of infrastructure depends on the materials on which it is built (subgrade). An important factor pertains to the degree of soil saturation, fluctuations in moisture content and the expected behaviour of the soil under saturated conditions. The type, strength or protection of subsurface conditions and materials may have to be modified to control and prevent soil saturation from damaging the overlying infrastructure.
- ***Material specifications*** – Materials of appropriate quality must be used in both unpaved and paved roads, and unsuitable materials may have to be replaced or enhanced to preserve the expected lifetime of the road or structure.
- ***Cross-section and standard dimensions*** – Standards may need to be revised, for example, to increase the crossfall of pavements in areas where one can expect a need to remove more water from the road. Similarly, standards (or guidelines) pertaining to road elevations or the vertical clearance of bridges may have to be revised upward.
- ***Drainage and erosion*** – Upgraded standard designs pertaining to drainage systems, open channels, pipes, culverts and surfacing options (e.g. for steep hill road sections) are needed to reflect changes in future expected runoff or water flow and consequential potential for damage caused by erosion.
- ***Protective engineering structures*** – These can be used to address rivers in spate, rising sea levels and storm surges. Protective structures may include drifts, dykes, seawalls, rocky aprons and breakwater systems.
- ***Maintenance*** – It is essential that all aspects of maintenance related to roads, drains and structures be diligently and timeously addressed. Most problems can be prevented by good maintenance.

3.2.2 Prioritisation of adaptation needs

Poor people struggle more than others to cope with and adapt to climate change and natural hazards (Oxfam, 2019; IPCC, 1995; Hallegatte et al., 2016). Not only are they more exposed and vulnerable to shocks, but the support they receive from families, communities, financial systems and government is also weaker, and they are often not granted a voice in decision-making processes. There is a downward spiral effect when climate affects economic development and creates loss of access at the same time.

Information Box 4

The World Bank's *Shock Waves* report (Hallegatte et al., 2016) states the following:

- Natural disasters push people into poverty and prevent poor people from escaping poverty.
- An increase in natural hazards is already observed and could worsen in the next decades. Some events considered exceptional today could become frequent in the long term, thereby threatening current living conditions.
- These changes in hazards could affect poor people and our ability to eradicate poverty. Because poor people are often more exposed to natural hazards than the rest of the population, and almost always lose a greater share of their assets and income when hit by a disaster, natural disasters could increase inequality and may contribute towards a decoupling of economic growth and poverty reduction.
- There are, however, many options to reduce risks for poor people. Although none are easy to implement, they do help reduce poverty and make the population more resilient to climate change. Examples include risk-sensitive land use regulation; more and better infrastructure; better housing quality and formal land tenure; air-conditioning; financial inclusion; and early warning and evacuation.

Whichever climate adaptation measures are implemented, they would almost inevitably increase the cost of providing new roads. They would be expected to also involve costs for the retro-fitting of adaptation measures to existing infrastructure or other measures to increase resilience or reduce risk.

Information Box 5

A World Bank study (Hughes et al., 2010) found that the **cost of adapting to climate change** – given the baseline level of infrastructure provision – is no more than 1 to 2% of the total cost of providing that infrastructure.

Chinowsky et al (2013) estimated that, based on six climate scenarios, the proactive and reactive costs for dealing with climate impacts are estimated to range, respectively, from an average of USD 22 million to USD 54 million annually per country. They further noted that:

- More than 85 per cent of rural feeder roads in Africa (i.e. those most susceptible to climate effects) were currently considered to be in poor condition and cannot be used during the wet season.
- The African continent lags behind global averages in road density based on both kilometres of road per population and density of roads compared with the area covered. Hence, road closures caused by consequences of adverse weather conditions may result in impaired accessibility (especially if no alternative roads are available).
- The potential degradation of roads from climate impacts presents a significant economic threat throughout the continent, but for countries with low GDPs in particular.
- At the time, AfDB called for USD 40 billion annually to mitigate the impacts of climate change: if a "No Adapt" policy is chosen, the impacts to road infrastructure could account for approximately 6 per cent of the funding. In comparison, an "Adapt" policy could reduce this cost to 1 per cent.
- The option of not adapting may appear to be beneficial as a policy in the short term (i.e. adaptation translates to increased spending; funding that could alternatively be utilised in health, education, etc.), but the long-term impacts ultimately make the "No Adapt" option detrimental to development.
- The Adaptation policy may result in an average saving of 74 per cent in total cost over the No-Adaptation policy, an average saving of USD 43 million per country annually.
- If a No-Adaptation policy is adopted, infrastructure development plans may have to be delayed as funding is reallocated to mitigate climate change damages. Associated with these delays is the potential for socio-economic development to be impaired as access to critical services and expansion of economic ties is delayed.

Climate resilience may decrease costs over a longer period by preventing damage to and interruptions of the infrastructure and by improving social conditions. In general, the cost of adaptation is small in relation to other factors that could influence the future costs of the infrastructure.

Adaptation will initially require a prioritisation of the needs. The process of prioritisation will require significant input from both road authorities and communities. Their differing needs and priorities may prevail and typically would require decisions of a strategic nature.

Recommendations for prioritisation

The following should be considered when prioritising investment decisions::

- Potential loss of life
- Availability of alternative routes
- Socio-economic costs and consequences of closure
- Environmental/sustainability issues
- Cost of repair
- Available funds
- Mobility and accessibility requirements

Generally, safety (loss of life) considerations should take precedence over the others. However, other than landslides, the safety implications of road failures are generally minimal.

With limited road funding available, there could be a need to ensure that the most “deserving” roads are treated first. The roads in a network (at national, provincial, state or local level) thus need to be classified in terms of various factors such as those listed in the box above. This includes whether a road is considered to be primarily for access or for mobility (Figure 10). Roads being used for mobility generally attract a higher priority for investment to ensure that they are affected minimally by “shock” climatic effects, not only to sustain socio-economic activity, but also to facilitate emergency responses and close-by access to isolated communities. The latter, however, would depend on the density of the primary and secondary road networks.

It is important that all roads are carefully and correctly classified in terms of their **required Levels of Serviceability (LoS)** as a part of the prioritisation process. This serviceability level will be a function of numerous factors, but mostly whether the road is purely an access road or whether it is also used for mobility. Various levels of serviceability can be defined based on certain variables, which should include the expected needs of the communities affected. Such a classification can be related directly to the required prioritisation as shown in Table 5 for *mobility* and in Table 6 for *accessibility*.

From a strategic planning and investment perspective, the classification of level of serviceability will address various scenarios of mobility and accessibility along a corridor, across a sub-region, regionally, and ultimately also nationally. In other words, priority and alternative route strategies can then be developed to ensure continuity of access through all climate events/seasons.

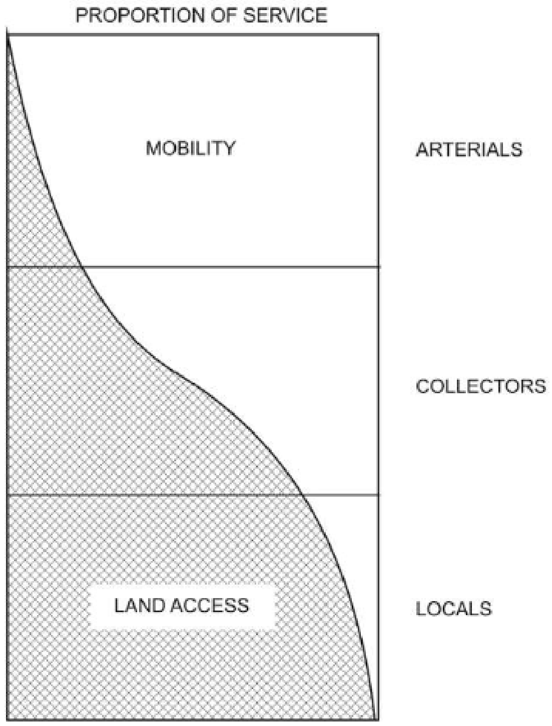

Figure 10: Accessibility versus mobility for road type (AASHO, 1964)

Table 5: Guidelines for levels of serviceability for mobility

	Required standards for mobility		
Level of serviceability	**Maximum roughness (IRI units in m/km)**	**Impassability**	**Duration of impassability**
5	11	≯ than 4 days/yr	≯ than 1 day
4	9	Never	None
3	8	Never	None
2	7	Never	None
1	6	Never	None

(Source: Paige-Green et al., 2019a)

Table 6: Guidelines for levels of serviceability for accessibility

	Required standards for accessibility		
Level of serviceability	**Comfortable driving speed (km/h)**	**Impassability**	**Duration of impassability**
6	N/A	> 20 days/yr	> 5 days
5	15	< 20 days/yr	Not more than 5 days
4	20	< 5 days/yr	Not more than 2 days
3	35	Never	None
2	50	Never	None
1	60	Never	None

(Source: Paige-Green et al., 2019a)

It should be noted that roads classified as LoS 1 could be those carrying higher traffic, leading to important services and usually not having an alternative route. Roads classifies as LoS 6 in Table 6 on the other hand could be those that serve very small relatively self-sufficient communities, who could handle loss of access for extended periods based on past experience.

Decisions on the classification of the level of serviceability should be based on a multi-criteria analysis (MCA) and need to include issues such as social, traffic, connectivity and economic considerations. These analyses should be done at a strategic level based on the inventory of roads developed as part of the Road Asset Management System (RAMS) for any country, as well as on asset condition ratings, in order to identify any improvements required.

For any given geographical area, it is unlikely that all roads will be passable all year, and there is likely to be a backlog of damaged roads or structures that will affect local passability. Therefore, accessibility levels should be addressed in a strategic manner, both along a particular road and also within a designated area of road network (whether it be at local, regional or national network level).

Strictly, localised socio-economic dependencies may play a major role in setting requirements for passability, as well as for the duration of impassability, and they may change the initial categorisation based on less localised access requirements.

Assessors carrying out visual condition assessments of road assets are expected to be trained to become more aware of the potential vulnerability of these assets to weather variability and climate change. The following should be considered in such assessments:

- The degree of exposure of the road infrastructure to local weather/climatic hazards
- The sensitivity of the infrastructure to such effects
- The adaptations necessary to mitigate the potential for damage (i.e. need for strengthening adaptive capacity)

The actions that can be taken to reduce vulnerability include avoiding, absorbing, and/or taking advantage of climate variability and impacts. Avoiding high-risk areas (e.g. floodplains) is probably not possible for existing roads, but could be considered for new infrastructure.

One of the biggest challenges to making infrastructure more climate resilient is predicting the timing and quantum of climate changes in relation to infrastructure design/service life. Table 7 outlines typical expected useful lives for some road infrastructure assets and their components based on the assumption that the assets have been designed, constructed and regularly maintained to meet the requirements of the functional environment in which they operate (COTO, 2013). However, if climate change projections were not accounted for in design, and the return periods of major storms were to change from, say, 50 years to 25 years, a reduction in the asset's useful life could be expected. Overall, the economic implications of these impacts on low-volume roads would be negligible, except for major structures such as embankments and bridges.

Table 7: Design life expectancy of several infrastructure types

Asset	Component Type	Name	Expected Useful Life
Road	Road Surfacings	Sand seal	3
Road	Road Surfacings	Slurry - Coarse	5
Road	Road Surfacings	Single Seal (All sizes)	9
Road	Road Surfacings	Single Seal (Mod. Binder)	12
Road	Road Surfacings	Double seal (All sizes)	10
Road	Road Surfacings	Double seal (Mod. Binder)	12
Road	Road Surfacings	Asphalt	14
Road	Road Surfacings	Asphalt Modified	16
Road	Road Pavements	Granular	20
Road	Road Pavements	Cemented	20

Asset	Component Type	Name	Expected Useful Life
Road	Road Pavements	Bituminous	20
Road	Road Pavements	Block Pavements	20
Road	Road Pavements	Concrete	30
Road	Formations including Drainage	Low Standard	30
Road	Formations including Drainage	Medium Standard	40
Road	Formations including Drainage	High Standard	50
Bridge	Bridge – General		80
Bridge	Bridge – Arch		80
Bridge	Bridge – Cable-stayed		80
Tunnel	Civil	Cut and Cover / Lined Rock	100
Drainage	Kerbs and Inlets		30
Drainage	Lined Drains	Concrete	30
Drainage	Bridge – Cellular		80
Ancillary	Retaining Wall		30
Ancillary	Retaining Structures	Gabions	20
Ancillary	Retaining Structures	Ground Anchors	40
Ancillary	Retaining Structures	Soil Nails	40
Ancillary	Retaining Structures	Soil Reinforcement	40
Ancillary	Walkway – Paved	Walkways - Bituminous	20
Ancillary	Walkway – Paved	Walkways - Blocks	25
Ancillary	Walkway – Paved	Walkways - Concrete	30

(Source: COTO, 2013)

Recommended actions (Roads/Transport MDAs)

- Categorise relevant existing road networks in terms of accessibility and mobility.
- Optimise network re-categorisation for optimal accessibility based on extreme anticipated weather cycles to be catered for.
- Base decisions regarding the classification of the level of serviceability on a multi-criteria analysis and include issues such as social, traffic, connectivity and economic considerations.
- Conduct these analyses at a strategic level, based on the inventory of roads developed as part of the Road Asset Management System (RAMS) for any country, as well as the existing condition, in order to identify any preliminary improvements.
- Alert assessors carrying out the visual condition assessments to the possible climate changes that may vary from one region to the next, and make specific visual assessments of potential road and structure vulnerabilities, based on the specific stressors identified for the individual countries or even regions within a country.

The following should be considered in this assessment:

- The degree of exposure of the road infrastructure to different climatic hazards
- The sensitivity of the infrastructure assets to such changes in climate
- The adaptations necessary to mitigate the potential for damage (inclusive of adaptive capacity)
- Socio-economic impacts
- Route alternatives to maintain access to vulnerable users

In many cases, older engineered roads in a country’s road network would be expected to be less affected by *gradual* changes in precipitation and temperature conditions. This is because these roads would more than likely have been upgraded or rehabilitated taking into account historical data on climate variability.

However, the increase in extreme events that is expected to occur in the shorter term needs to be catered for on existing roads (and networks).

Information Box 6: Assessing cost options

Each proposed project should be assessed in terms of the costs of adaptation versus the cost of doing nothing, taking into account all of the engineering, social and environmental costs and the discounted overall life-cycle costs to allow fair comparisons. The overall economic impacts are, however, expected to be massive. As an example, the World Bank has estimated that climate change has the potential to result in a $3.1 billion impact on roads in Ethiopia (through to 2100) when the effects of temperature, precipitation and flooding increases are taken into consideration (World Bank, 2010). It also indicated that these costs could be reduced by 54% if adaptation policies were to be adopted through policy changes by the government. However, even with these adaptations, the potential cost to Ethiopian roads resulting from climate change could be as high as $1.4 billion (Chinowsky et al., 2011)

Recommended actions (Roads/Transport MDAs)

- Avoid the risk (often impracticable).
- Remove or reduce the risk to a level that minimises the consequences so that they can be handled by using existing resources – make use of appropriate technological solutions.
- Implement appropriate adaptation measures.

3.3 Embedment

Embedment aims to incorporate or place climate change issues in policies, strategies and plans, as well as in decision support systems such as Road Asset Management Systems (RAMS). Embedment covers the preparation of full documentation, the implementation thereof and delivery of the adaptation process. The following documentation would be expected to account for climate variability and change as part of the adaptation process:

- Policy documents
- Strategic and five-year plans
- Management plans
- Planning documents
- Programmes and budgets
- Standards and specifications
- Project plans and designs
- Construction and monitoring plans
- Contingency plans

3.4 Capacity building

In order to establish and implement climate adaptation successfully, national capacity should be developed across all relevant stakeholders. This includes roads/transport MDAs, and should include a wide range of participants from central government agencies (e.g. Finance, Environment, Agriculture, Forestry, Water, etc.) cascading all the way through to village groups.

The following activities should be considered for systematic capacity building (can be provided by institutions with expertise or through contracting experts):

1. **Engaging stakeholders on capacity development**
   An effective capacity building process must encourage participation by all those involved. Engaging stakeholders who are directly affected allows for more effective decision making; it also makes development work more transparent.

2. **Assessing capacity needs and assets**
   Assessing pre-existing capacities through engagement with stakeholders informs what areas require additional training, what areas should be prioritised, and in what ways capacity building can be incorporated into local and institutional development strategies.

3. **Formulating a capacity development response**
   The capacity building response could be based on the following:
   - Leadership – high-level involvement will help priority setting, communication and strategic planning;
   - Institutional arrangements – policies, procedures, resource management, organisation, leadership, frameworks, and communication;
   - Knowledge – the extent of knowledge on climate adaptation matters, curriculum development at tertiary education institutions should also be addressed to build grass-root knowledge on climate change and related adaptation and mitigation;
   - Accountability – the implementation of accountability measures facilitates better performance and efficiency.

4. **Implementing a capacity development response**
   Implementing a capacity building programme should involve the inclusion of multiple systems: national, local and institutional. It should involve continual reassessment and expect change depending on changing situations. It should also include evaluative indicators to measure the effectiveness of initiated programmes.

5. **Evaluating capacity development**
   Evaluation of capacity building promotes accountability and feeds into a programme of continuous improvement.

Based on experience gained through consultations on needs analysis at hands-on workshops held in Ethiopia, Ghana and Mozambique, the following actions can be recommended:

<u>Recommended actions</u>

- Demonstrate engineering adaptation methodology on a project site to create the opportunity for local practitioners to become involved in site investigations, in the identification of appropriate adaptation options (and the reasoning behind those), the design phase, the construction phase (with due attention to quality of construction), and subsequent monitoring and evaluation.
- Provide ‘soft’ demonstrators to guide practitioners through the following processes:
  - Identifying vulnerable districts and road links within a district, using the vulnerability assessment framework (see **Climate Risk and Vulnerability Assessment Guidelines**), and empowering trainees to apply this methodology on a wider scale.
  - Embedding ‘climate adaptation’ in road asset management systems so as to support prioritisation and decision making, based on a broader spectrum of attributes besides present road conditions. This would also require road condition assessors to be trained to identify potential environment-related risks and threats within and outside the immediate road environment.
- Develop dedicated training material on all aspects related to risk management and resilience optimisation, which could be used as a basis for the training of public and private sector practitioners in how to address climate variability and change.
- Curriculum development for engineering and non-engineering adaptation to climate change (Engineering education facilities - need to engage government institutions responsible for tertiary education)

Initially, there should be an emphasis on **awareness and knowledge building**, followed by dissemination, capacity building and uptake. Training and capacity building will be important for

- *understanding* the challenges;
- *participation* and knowledge sharing/exchange;
- *agreeing* on a methodology and programme for climate adaptation;
- *developing* physical and social resilience; and
- *disseminating* knowledge and experience.

Specific attention will be needed for national road fund boards, scientific ministries and environmental agencies, with the cooperation and buy-in of the road authorities.

Recommended actions:

- Conduct high-level government briefings and workshops to create awareness, understanding and a shared responsibility for addressing climate change challenges (National Climate Change institution possibly linked to environmental ministries).
- Establish a national climate adaptation department with a responsible officer (Central government, could also be through an environmental ministry).
- Produce standard training materials to be used by trainers across all MDAs and shareholders (climate science departments or institutions).
- Establish a knowledge-exchange network (e.g. web-based) between organs of state, the private sector and academia (Role of tasked climate science department or institution).
- Include innovative aspects such as how to assess and manage current maintenance backlogs already caused by extreme climate effects (Roads/Transport MDAs).
- Participate in international knowledge-exchange networks, particularly those involved in the dissemination of information (Part of a national network, Roads/Transport MDAs need to participate).
- Disseminate potential options for climate adaptation, as well as resilience strategies (Related to the domains of Roads and Transport MDAs).
- Conduct knowledge-sharing/dissemination workshops and national/regional/local training workshops (Related to the domains of Roads and Transport MDAs).

4 Approach and Delivery

4.1 Funding and climate vulnerability screening

Finding the necessary funding to implement climate resilience is one of the biggest challenges for road authorities. Funding has for many years been insufficient to maintain the existing infrastructure. An estimated $93 billion per year for the next decade would need to be invested if Africa is to fill the overall infrastructure gap (Cervigni et al, 2017). Response to current extreme events results in funding being diverted from other sources, usually from maintenance budgets to “emergency” funds, thus exacerbating the already underfunded maintenance requirements. Sourcing the necessary funds for climate resilience could be a major challenge for road authorities, and innovative funding pipelines need to be developed.

Until recently, most development partners have not yet started implementing robust risk, screening and adaptation methodologies for road infrastructure projects. Experiences are not well developed or documented, which has led to cases of insufficiently resilient assets. Recent strategies for multi-sectoral programmes and projects by development partners (OECD, 2017) are summarised below.

World Bank Group

In line with the World Bank Strategy (2014), its fund for the poorest countries (International Development Association, IDA) currently

i) incorporates climate and disaster risk considerations into the analysis of development challenges and priorities, and, when countries agree, in the content of programmes and frameworks;
ii) screens all new project and sectoral/national programmes for climate risks.

The fund focuses on the private sector in developing countries (International Finance Corporation or IFC), and follows Performance Standards that define private sector client responsibilities for managing environmental and social risks. These include identifying climate risks and adaptation opportunities, and promoting the sustainable use of energy and water resources.

Asian Development Bank (ADB)

Since 2014, the ADB has institutionalised a framework to Guidelines for climate proofing investments for road transport have been in place since 2011.

i) systematically identify proposed investments that may be adversely affected by climate change during the very early stages of project development; and
ii) incorporate risk reduction measures in the project design.

(See also Information Box 7.)

African Development Bank (AfDB)

Alongside the Climate Risk Management and Adaptation Strategy (AfDB, 2009), AfDB’s Climate Change Action Plan 2011-2015 (AfDB, 2010) sets out to develop tools and mechanisms to assess vulnerabilities and build climate resilience into its projects. The AfDB Climate Safeguard System (CSS) tool to assess vulnerabilities, screen risks and identify adaptation options was piloted in 2013.

European Bank for Reconstruction and Development (EBRD)

EBRD systematically integrates climate risk assessments and adaptation measures into their investment operations by conducting climate sensitivity screening, tailoring asset design and management, training employees to manage risks, and creating adapted financial solutions. Tools for risk screening are in place. Detailed analyses, with sector-specific tools, are currently in development.

Nordic Development Fund (NDF)

The Nordic Development Fund (NDF) initiated work (undertaken by the Finnish Overseas Consultancy) to assist road sector MDAs in countries in Africa (focusing mainly on Mozambique) to develop their competence to deal with climate resiliency in the roads sector. The objective is to provide stakeholders with capacity and tools to manage climate threats to road development during planning, design, construction and maintenance. It forms part of a broader objective to develop a sustainable East-West road transport link between Malawi, Zambia and Mozambique to increase national and regional connectivity.

Information Box 7

Asian Development Bank will support country-driven climate change adaptation programmes primarily by (i) promoting the mainstreaming of adaptation and disaster risk reduction into national development plans and ADB country partnership strategies; (ii) helping build the climate resilience of vulnerable sectors such as agriculture, energy, transport and health, including preparation of climate resilient sector road maps; and (iii) assisting the Developing Member Countries with climate proofing projects (ADB, 2014). Specifically, ADB is supporting efforts to (i) integrate climate change risk management and disaster risk reduction into national development strategies, sector plans, and investment projects; (ii) enhance capacity of governments, communities and civil society to anticipate and manage climate risks; (iii) generate and disseminate climate change data, information and knowledge; (iv) promote regional partnerships to facilitate information and knowledge sharing; and (v) leverage finance for adaptation.

4.2 New infrastructure and structures

For new infrastructure, it is essential that the design includes all of the necessary adaptations to ensure that the facilities are resilient. This also implies that design guidelines must be appropriately adjusted for climate change implications. It could most likely (depending on applied discount rates (Stakhiv, 2011)) increase the total project cost (often quite significantly), but since the facility would be expected to last at least 20 years with probably only routine maintenance (for roads) and between 50 and 100 years for larger structures, appropriate design should ensure significant benefits over the long term, when the climate is almost guaranteed to change.

4.3 Rehabilitation and retrofitting

It is generally more difficult to apply adaptation measures to existing than to new infrastructure. However, most components of the existing infrastructure are designed to perform under the expected worst conditions and include some redundancy. Conditions are likely to change over time, but mostly not to exceed the expected worst conditions. A well-designed road or structure, if properly maintained, should resist periodic extreme events with minimal damage.

Thus, in the case of retrofitting, the first and most cost-effective consideration should be to ensure that the facility is properly maintained. Localised damages should be repaired, drainage structures be cleaned, their effective operation be ensured and excessive vegetation be removed.

During this process, as well as during routine visual condition and climate resilience assessments, other deficiencies that require improvement will normally be noticed. These are expected to generally require more extensive work and resources, and can then be included in plans for additional "retrofitting", as and when funding permits. Visual assessment processes should also be expanded to incorporate climate risk and vulnerability content. The *Visual Assessment Manual* (Paige-Green et al., 2019b) summarises the important potential climate-related problems and indicates the method of assessing them, with pointers that can assist with the observations and the interpretation of the visual assessments. It uses an assessment checklist that incorporates component groups such as erodibility, sub-grade problems, drainage, slope stability, construction and maintenance, all of which are considered in the light of climate change effects (See the *Visual Assessment Manual* for detailed information).

4.4 Maintenance

Weather variability and the short- and long-term effects of climate change could necessitate more frequent, and probably different, maintenance of road infrastructure (access roads, geotechnical structures, bridges and drainage structures), which would have an impact on the budgets of road authorities.

Recommended actions

- Identify the most cost-effective adaptation options to design and construct assets that are more climate resilient and to ensure that (all-weather) rural accessibility can be sustained.
- Develop and implement risk-reduction climate adaptation strategies and action plans.
- Perform periodic maintenance with a view to rectifying emerging problem areas.
- Allocate funding for emergency repairs and for short- to long-term climate strengthening of infrastructure.

For affected infrastructure that is already in place, preparing emergency and maintenance contingency plans and budgets would enable quicker response for the most vulnerable areas. This should reduce extended periods of road closures and more serious consequences of disasters.

Condition assessment and performance modelling should be improved by the following actions:

- Identifying and prioritising high-risk areas and highly vulnerable assets
- Using smart technologies to monitor the condition of infrastructure assets
- Keeping records of maintenance activities, including specific location
- Keeping records of road closures due to, for instance, flooding.

4.5 'Low-cost' scenario

The adoption of a '*Low-cost' scenario* ("Do minimal") can be expected to cause frequent disruptions to the infrastructure network, generally cost significantly more and take longer to restore passability. By necessity, this option is becoming much more prevalent as maintenance backlogs increase and funding becomes more problematic. Unfortunately, if it is part of a *reactive* management programme, it becomes difficult to address affected communities in any realistic prioritisation programme. In many circumstances, the budgeted funds are simply not enough to deal with all affected areas, roads and structures, or the consequences of climate change are simply too severe to justify comprehensive physical adaptation. Selection should then occur on the basis of socio-economic effects and cost-benefit analyses. A planned programme of dialogue with affected communities, well-dispersed information and contingency programmes are necessary to minimise the adverse effects of these decisions.

The consequences of insufficient emergency funds or backlog maintenance are that routine maintenance and/or planned rehabilitation is often suspended. Many African countries are experiencing chronic shortages of funds. In some cases, roads or structures are abandoned due to a lack of funds or because of strategic decisions during adaptation prioritisation. In others, road infrastructure assets can be left impassable during rainy seasons or part thereof.

Where budgets are inadequate or absent, the guidelines proposed under the 'Low-cost' Scenario should be followed (see Sections 2.3.3 and Section 3 of this guideline).

4.6 Management of delivery

Figure 11 illustrates the likely choices and strategic approaches to infrastructure development and management.

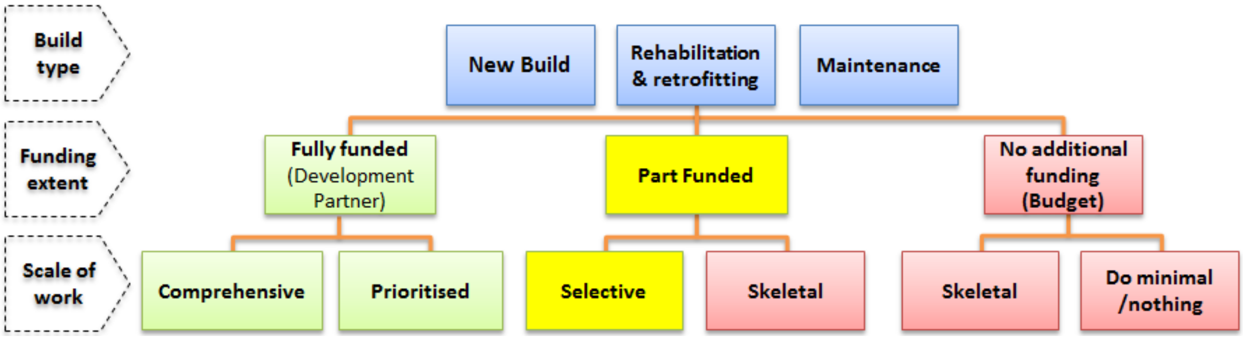

Figure 11: Hierarchy of delivery systems for climate resilience

The upper level consists of new construction, rehabilitation/retrofitting and maintenance needs. In sub-Saharan Africa, new construction is typically funded by donor partners or aid programmes, as shown in green in Figure 11. Most development projects are also fully funded, but some may require additional funding from within the countries' treasury. Generally, there are few financial problems in this regard.

Rehabilitation/retrofitting, on the other hand, may be partly funded by outside agencies but mostly by the national treasury (often augmented through dedicated Road Funds), as shown in yellow. This is likely to be applied selectively to high-priority projects, with other projects obtaining little or no funding.

Maintenance is generally funded entirely from local sources and often, inevitably significantly underfunded (marked red in Figure 11). It is clear from the figure that only selected high-priority projects can usually be undertaken and the remainder of the infrastructure network are likely to be dependable on reactive operations after climatic events. Rehabilitation and retrofitting may receive partial funding for selective high-priority programmes, while the remainder of the infrastructure network could be subjected to operational budgets that, in many cases, result in a '*do-minimal*' or *'no-adapt'* scenario. It is recommended that, in these circumstances, the guidelines set out in Sections 2.4.4 and throughout Section 3 be followed in terms of the *'Low-cost'* scenario. Doing nothing or very little can result in loss of control, unforeseen problems, possible chaos and potentially loss of life.

5 Effective Data Management

The use of data is critical to support planning, decision making and prioritisation. The latter often rely on systems and tools deployed in institutions that deal with road infrastructure, to be operational and sufficiently comprehensive. Asset management systems play an important role in managing infrastructure, planning projects and maintenance, and assessing the overall state of roads and related structures.

5.1 Data and Asset Management

Asset management is an overarching business model that provides the framework upon which climate change initiatives can be readily implemented by a road authority. Furthermore, data on road and asset conditions is not collected comprehensively or routinely in most sub-Saharan countries. Data collection is generally based on visual assessment with some measurements taken, and automatic data collection is rare. The following figure illustrates such a visual assessment form (See the *Visual Assessment Manual* (Paige-Green et al., 2019b) for detailed information).

Road Number:	A002	Date	03/04/2019	Assessors:	XY & ZA	Weather:	Sunny & Hot	Topography	Rolling

Chainage	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	0.1	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9	2
Grade	Flat	Flat	Flat	Flat	Medium downhill	Medium downhill	Flat	Medium downhill	Medium downhill	Flat embankment	Flat embankment	Flat embankment	Flat embankment	Flat embankment	Bridge	Flat	Medium uphill	Medium uphill	Medium uphill	Medium uphill	Gentle uphill
Access to facilities	School	School	School	School	School	School	School	School	School	School	School	School	School	School	School	School	School	School	School	School	School
Alternative roads	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None
Common vehicle types	Light Utility vehicles	Light Utility vehicles	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars	Motor Cars
Land-cover / land-use	PU	PU	PU	PU	PU	PU	PU	PU	PU	PU	F	F	D	PU	PU	PU	PU	PU	PU	PU	PU
	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Forest/Dense vegetation	Forest/Dense vegetation	Degraded land	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban	Peri-Urban/Urban
GPS Location																					
Photo No.																					
Erodibility																					
Subgrade	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Road surface - unpaved	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Side drains - unlined	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Embankment slopes	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Cut slopes	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Subgrade problems																					
Material type	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Moisture	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Drainage (in reserve)																					
Road shape	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Shoulders	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Side slopes	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Side drains	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Mitre drains	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Drainage (streams)																					
Structure	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Approach fills	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Erosion of stream banks	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Protection works	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Flood plain	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Slope stability																					
Cut stability	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Fill stability	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Construction																					
Overall finish	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Erosion protection works	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Maintenance																					
Quantity	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
Quality	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
COMMENTS:																					

COMPUTED INDEX VALUES

Chainage	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	0.1	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9	2
Deficiency score (DI)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maintenance score (Mn)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Criticality score (Cr)	3.9	3.9	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Road Vulnerability Index (RVI)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Max subcategory score (excluding maintenance)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Deficiency score (overall average)	0.0	Di
Maintenance score (overall average)	0.0	Mn
Criticality score (overall average)	3.6	Cr
Road Vulnerability Index (overall average)	0.0	RVI
Bad section / red flag indicator	No	(excl maintenance)

Figure 12: Visual assessment form for climate adaptation.

For climate adaptation, additional information needs to be collected to assess potential risk/vulnerability, so that potential problem areas/structures can be identified. Shock events related to climate occur frequently, even within the lifecycle of the shorter-lived road assets, and therefore they need to be considered part of the day-to-day business of road authorities. Such business includes preparing in advance for the events; how to respond during an event; and what is to be rebuilt (and how) after the event to ensure the network is more resilient before the next shock event occurs.

Figure 13 categorises assets according to those that do not require adaptation and those that could benefit from adaptation. It also reflects preferred philosophy for dealing with adaptation.

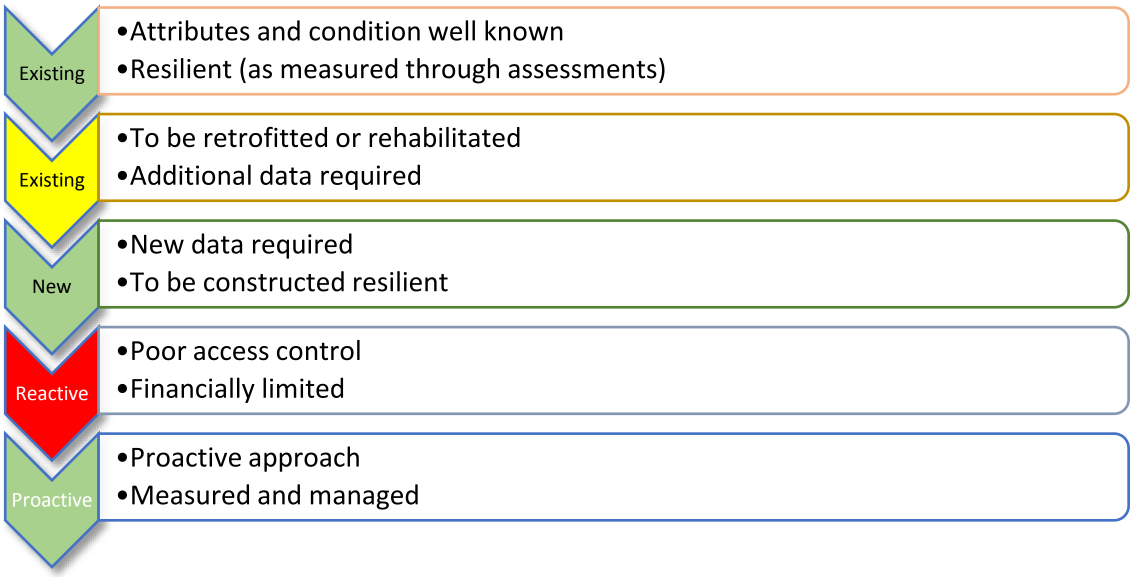

Figure 13: Assessment of road assets for prioritisation and budgeting

The World Bank's Technical Report on Integrating Climate Change into Road Asset Management (Henning et al., 2017) guides road authorities on how to go about integrating thinking on climate change into their business-as-usual asset management processes. It sets out how a typical Asset Management (AM) process should respond before, during and after a shock event (see Figure 14). Most items need to be in place already to be utilised when a shock event occurs. Not all recommended actions will be applicable to all road authorities, although it is certainly advisable to at least consider each within the overall asset management improvement process. In extreme cases, these steps may go as far as the abandonment of certain road assets that cannot be reasonably protected from climate change.

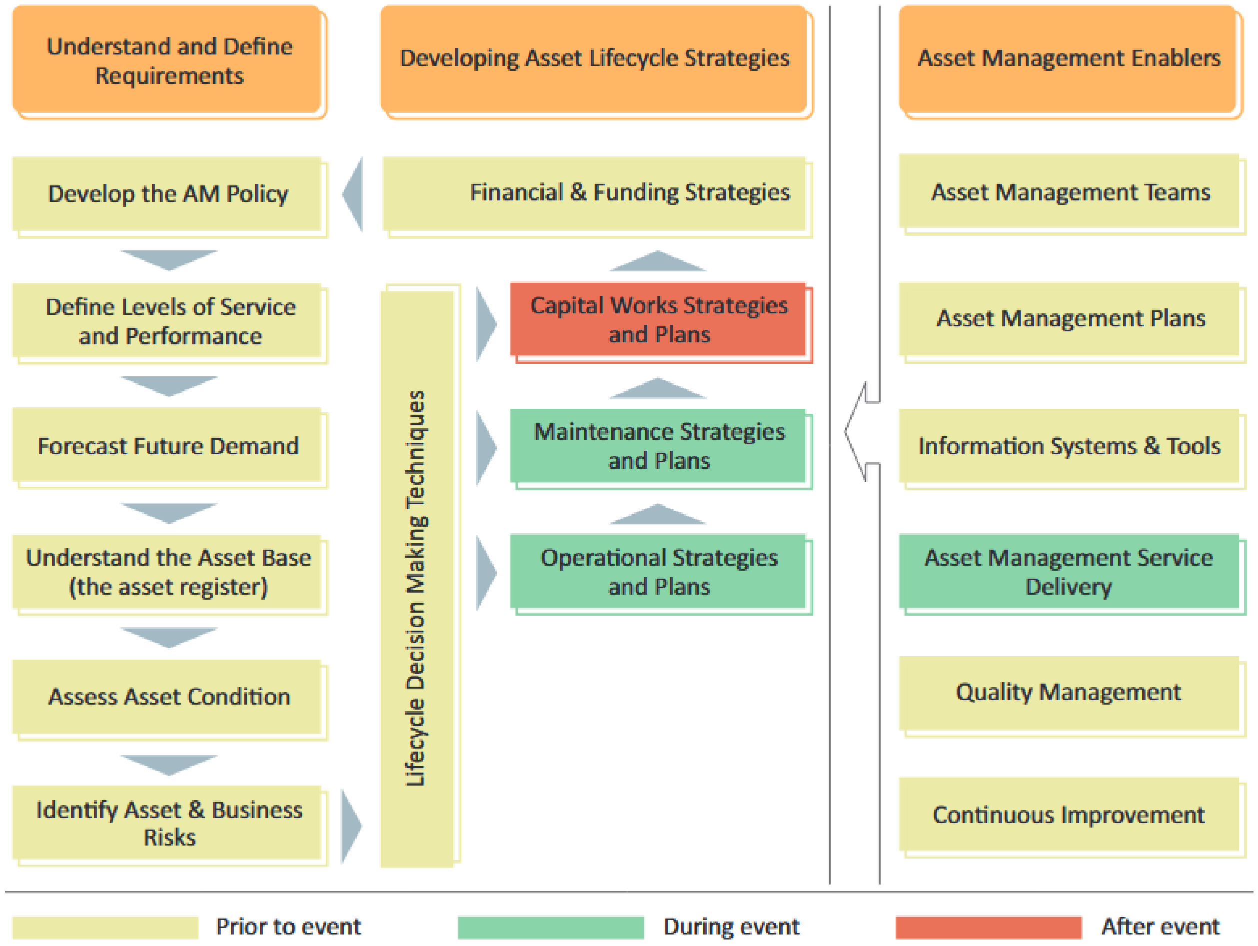

Figure 14: Asset management process versus response timing (NAMS, 2011)

The following two tables (Tables 8 and 9) cover recommended actions to integrate climate change into Asset Management (AM) systems (Henning et al., 2017).

Table 8: Recommended actions to integrate change in AM practices (NAMS, 2011)

Phase	Step	Key Additional Actions
Understand and define requirements	**Develop the AM policy**	• Specifically address climate change within the AM Policy statement, including what horizon is to be planned for. • Have agreements in place on how the damage from major events will be funded and who will be entitled to financial support.
	Define levels of service and performance	• Ensure network resilience measures (e.g. restore all major roads within 12 hours of end of 1:100-year flood) are included in the level-of-service framework. • Revise design guides to consider the changing frequency of climatic events.
	Forecast future demand	• Integrate future demand forecast (such as demographical changes and traffic loading increases) with climate change impacts on the expected performance of infrastructure. • Avoid providing for future growth in areas of high vulnerability.

Phase	Step	Key Additional Actions
	Understand the asset base	• Ensure that data on drainage assets and their vulnerabilities/ deficiencies is complete and up to date. • Geospatially reference all data collection processes. • Highlight interdependencies with other infrastructure by means of road data and information. • Link life-lines and critical interactions between asset groups in the base data.
	Assess asset condition	• Collect data that includes the measuring and recording of specific climatic effects on road network • Focus on quantifying the vulnerabilities of pavements to temperature and moisture changes.
	Identify asset and business risks	• Recognise climate change as a risk to the asset and to the delivery of services. • Conduct risk and vulnerability assessments for climate adaptation. Integrate these processes with risk management from an organisational risk perspective (the integration with asset management risk in particular promises significant efficiency gains).
Develop asset lifecycle strategies	**Use lifecycle decision-making techniques**	• Road asset management and systems bring a wealth of analytics to the climate adaptation topic area • Incorporate multi-objective capabilities in current analysis processes. • Place more emphasis on community involvement when bringing climate adaption into the asset management decision-making process.
	Apply operational strategies and plans	• Include specific allowance for identifying and addressing deficient adaptation measures in operational plans – such as making sure drainage structures are cleaned and without blockages. • Include retrofitting of infrastructure that is found to be significantly deficient. • Trial new materials that may better resist climate change. • Include policies and processes identified for responding to disasters in operational procedures
	Introduce maintenance strategies and plans	• Make specific allowance for and focus on addressing items that limit the impact of climate change.
	Update capital works strategies and plans	• Update current design criteria (such as drainage design) to allow for changing rainfall patterns. • Give specific consideration to climate adaptation technologies in new designs.
	Apply financial and funding strategies	• Investigate the impacts of different investment scenarios on climate adaptation. • Introduce financial and funding strategies for responding to potential disaster events.

Phase	Step	Key Additional Actions
Asset management enablers	**Appoint an asset management team**	• Drive the effective integration of climate adaptation and asset management from executive management levels within organisations. • Appoint someone as the climate change champion to drive all these actions throughout the organisation.
	Introduce asset management plans	• Ensure that the AMP specifically addresses climate change.
	Provide information management systems and tools	• Include the recoding of specific climatic and impact data in information management systems for planning purposes. • Put a data residence plan in place to respond to disaster planning needs.
	Ensure asset management service delivery/ procurement	• Ensure that legislation and procurement processes allow for an appropriate response to shock events.
	Provide quality management	• Ensure the sufficient functioning of climate adaptation measures by providing quality management.
	Ensure continuous improvement	• Identify the improvements that are necessary for climate change adaptation.

Table 9: Recommended adaptation strategies and monitoring techniques for the components of the asset management system (Ebinger and Vandycke, 2015)

Asset Management System Component	Monitoring Techniques and Adaptation Strategies
Goals and policies	Incorporating climate change considerations into asset management goals and policies. These could be general statements concerning adequate attention to potential issues, or statements targeted at specific types of vulnerabilities (e.g. sea-level rise).
Asset inventory	Mapping infrastructure assets in vulnerable areas by potentially using GIS. Making an inventory of critical assets that are susceptible to climate change impacts.
Condition assessment and performance modelling	Monitoring asset conditions and environmental conditions (e.g. temperature, precipitation, winds) to determine if climate change affects performance. Incorporating risk appraisal into performance modelling and assessment. Identifying high-risk areas and highly vulnerable assets. Using “smart” technologies to monitor the health of infrastructure assets.
Alternatives evaluation and programme optimisation	Including alternatives that use probabilistic design procedures to account for the uncertainties of climate change. Perhaps also applying evaluation criteria related to climate change, smart materials, mitigation strategies, and hazard avoidance approaches.
Short- and long-range plans	Incorporating climate change considerations into activities outlined in short- and long-range plans. Incorporating climate change into design guidelines. Establishing appropriate mitigation strategies and agency responsibilities.

Asset Management System Component	Monitoring Techniques and Adaptation Strategies
Programme implementation	Including appropriate climate change strategies into programme implementation. Determining if agency is actually achieving its climate change adaptation/ monitoring goals.
Performance monitoring	Monitoring the asset management system to ensure that it responds effectively to climate change. Perhaps also making use of climate change-related performance measures. Using "triggering" measures to identify when an asset or asset category has reached some critical level.

5.2 Slope management system

Where appropriate, it is also advisable to include, as part of the Asset Management System of all road authorities, a basic *Slope Management System* (SMS) that identifies the potential for failure and the consequences of failure of all slopes within their jurisdiction. Such systems classify the stability of earth embankments and cut slopes, which allows those most likely to fail under extreme precipitation events to be prioritised for stabilisation interventions. It should be noted that such interventions are usually expensive and should be analysed and designed by experienced geotechnical engineers. General road practitioners are seldom sufficiently experienced to identify the optimum types of stabilisation measures or design their installation locations and properties. This might be required that geotechnical engineers be employed or that engineers within Roads/Transport MDAs be trained if dealing with slope management. It is useful to integrate stabilisation measures with slope failure incident maps or to develop them independently of the SMS. Landslide susceptibility can be represented as maps, as can be seen in Figure 15.

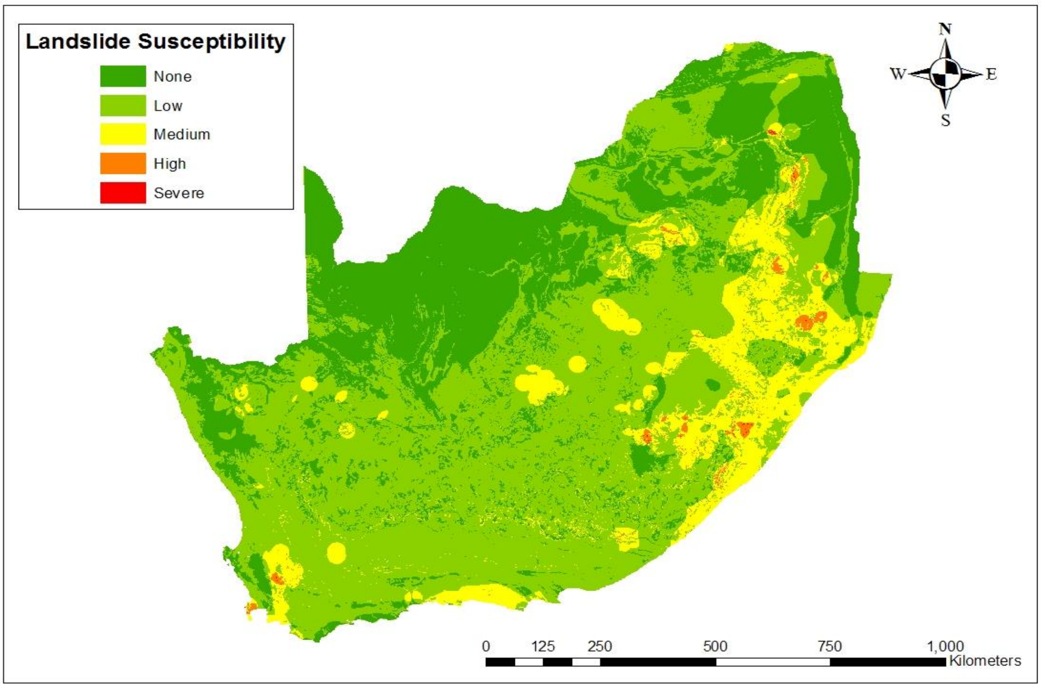

Figure 15: Example of a typical landslide susceptibility map for South Africa

Recommended actions

- Introduce a slope management system (SMS) within relevant roads authorities that should include the following:
  - Assessment and identification of potentially unstable slopes
  - Prioritisation of high-risk slopes that require remedial action
  - Design of appropriate stabilisation measures as part of the climate resilience plan
- Consider the implementation of slope failure incident maps, either integrated with, or developed independently of an SMS. (within the Roads/Transport MDAs)

5.3 Collect and analyse data and information

Each African country has a climate change focal point under the United Nations Framework Convention on Climate Change (UNFCCC). Several countries have also prepared national adaptation programmes of action to identify their most urgent adaptation needs. All the available data covering climate change and patterns should be identified and analysed for its usefulness. Data is seldom centrally accessed (on a country level), as multiple institutions within a country can deal with climate and environmental data. It is advised that such information be coordinated by identified institutions to ensure its shared use. The same applies to the inventory of infrastructure assets and their condition. Identification of all climate parameters relevant to the project, as well as collection and collation of data is required. This could entail collaboration between responsible roads institutions and those dealing with climate risk assessments. In addition, detailed assessments can include localised climate data that has to be linked to such systems.

Recommended actions

- Assess the following parameters and data:
  - Sea level rise, wave action and coastal erosion risk (for coastal roads)
  - Precipitation intensity and slope (for mountainous regions)
  - Peak rainfall events (for designing drainage and protecting infrastructure)
  - Profiles of past extreme weather events
  - Changes to the onset of rainy seasons (for road maintenance and construction scheduling)
  - Wind speed (for erosion and wildfire hazard assessments)

Identifying the method(s) for the assessment and prioritisation of options, such as cost-benefit analyses or multi-criteria analyses, will also ensure that the relevant data is collected during project preparation.

5.3.1 Determine classifications and methods of assessment

All roads should be carefully and correctly classified in terms of their required levels of serviceability as a part of the prioritisation process. This serviceability level will be a function of numerous factors, but mostly whether the road is purely an access road or whether it is also used for mobility. (Such a classification can be directly related to the required prioritisation as shown in Table 5 for mobility and in Table 6 for accessibility – see Section 3.2.2.)

As it is not economically possible to address every potential climate resilience problem, it is necessary to prioritise the roads within an area. Such prioritisation should be based on the level of serviceability provided by the road. Decisions on the **classification of level of serviceability** should be based on multi-criteria analyses (MCA) and include social, traffic, connectivity and economic considerations. These analyses should be done at a **strategic level,** based on the **inventory of roads** developed as part of the Road Asset Management System (RAMS) as well as existing road conditions, to identify any preliminary improvements.

The following should be considered in this assessment:

- Degree of exposure of the road infrastructure to different climatic hazards
- Sensitivity of the infrastructure to such changes in climate
- All adaptations necessary to mitigate the potential for damage (inclusive of adaptive capacity)

The actions that can be taken to reduce vulnerability include avoiding, absorbing and/or taking advantage of climate variability and impacts. Avoiding high-risk areas is probably not possible for most existing roads, but could be considered for new infrastructure.

5.3.2 Method of assessment

To implement the necessary adaptations to make roads more climate resilient and assist with prioritisation, it is necessary to carry out visual assessments of existing roads – with particular attention being paid to those problems specifically related to climatic effects.

In addition to the normal pavement surfacing integrity, problems related to climatic effects include the following:

- Erosion potential
- Subgrade material problems
- Drainage efficiency in the road reserve
- Drainage from outside the road reserve
- Slope stability
- Construction quality
- Maintenance effectiveness

Other indications of possible problems may be observed on certain sites, such as the accumulation of sand and debris (due to wind and flooding), as well as excessive vegetation caused by increased rainfall and high temperatures, and leading to sight-distance and passability problems, etc.

The assessor will usually move along the road (preferably walking or in a slow-moving vehicle if necessary) and assess the above features at relevant points along the road. Typically, the data sheet (see example in figure 12) is expected to be completed after every 100 m with locations of any problems highlighted in the problem row. This differs from normal visual condition assessment for Asset Management which is generally done from a moving vehicle (at up to 80 km/h) over a full road link (3 to 5 km) with occasional stops. The assessment of climate resilience requires additional training and experience.

It must be remembered that the information obtained pertains only to the observations at the time made, and it needs to be carefully interpreted to identify potential longer-term or more severe problems. Since recent maintenance prior to the visual assessment may affect the observations by masking potential problems, it must be borne in mind that the objective is to identify likely areas where adaptation measures are necessary to improve the climate resilience of the road.

5.3.3 Role of assessors

Assessors carrying out the visual condition assessments should be trained and be made **aware of the possible local climate impacts.** They are expected to make specific visual **assessments of potential road and structure vulnerabilities,** based on the specific nationally agreed stressors.

Recommended actions (for assessors of Roads/Transport MDAs)

- Consider the following issues in this assessment:
  - The degree of exposure of the road infrastructure to different climatic hazards
  - The sensitivity of the infrastructure to such changes in climate
  - The adaptations necessary to mitigate the potential for damage (inclusive of adaptive capacity).

6 Climate Risk Screening

A geospatial climate-related road infrastructure risk and vulnerability assessment can provide key geographic information aimed at supporting decision makers to identify those roads that should be prioritised for repair, improvement or development, due to changing climatic conditions. Climate risk screening is an activity that did in most cases not previously form part of assessments and planning considerations in Roads/Transport MDAs. These MDAs might use geospatial information system and data already; however climate change content might be new. As such it introduces a new element within the roads institutions. It therefore requires capability development in order to collect data, analyse data to produce information that can support planners and be added to planning and management systems.

This section refers to the **Climate Risk and Vulnerability Assessment Guidelines.**

The scale of application affects the level of detail and the nature of decision support provided by a risk and vulnerability assessments. Climate risk screening for roads might need to happen at different scales. Initially at a national scale, where climate vulnerability as well as identified threats and adaptation strategies, provide strategic-level support for national road and climate policies. At finer scales, regional and district-level analyses still play a vital role in informing future planning and development decisions by prioritising high-risk areas. Local scale climate risk screening would also require more detailed project-level assessments that support project managers in the process of adapting individual stretches of road or road corridors. Introducing climate risk screening in roads institutions introduces change as it adds data. This however also requires and understanding of climate science, correctly applying such information, and detecting climate change issues affecting road infrastructure. This might identify a number of needs (gaps) to be addressed mostly within roads institutions.

6.1 Needs determination

A survey of affected countries, followed by meetings with relevant government officials and workshops, has revealed similar experiences and problems to be addressed urgently:

- Acknowledgments that climate risks and vulnerabilities need to be addressed (mind-set change).
- Climate adaptation is often addressed as part of a multi-sectoral national approach, but transport and roads are not currently included in any meaningful way. Transport institutions should address this and ensure that they are properly represented in the national climate change adaptation landscape.
- Relevant climate-related data needs to be collected to support a new approach and has to be applied in the context of planning as well as linked to asset management systems. This would require strengthening of knowledge and capacity on climate adaptation, and the roads institutions need to link and network with climate science institutions
- Appropriate climate change adaptation policies and strategies need to be developed within roads institutions and embedded in plans, programmes and projects.
- It is acknowledged that road damage backlogs due to climatic effects are increasing and that there is a need for appropriate guidance for addressing this.
- Maintenance budgets are not adequate to deal effectively with climate effects requiring better *return on investment* and help with a *Do Nothing/Minimal* approach.

Recommended actions (by Roads/Transport MDAs)

- Carry out needs analyses within the Roads and Transport sector to identify the scope of the required activities and the outputs needed.
- Consult with all relevant stakeholders to establish clear communication and cooperation lines.
- Link or collaborate with other institutions that deal with climate change research.

6.2 Identify and mobilise stakeholder/partner involvement

Stakeholder communication and involvement should occur from the outset and should be ongoing throughout the assessment process, and should be facilitated through collaborative work sessions and workshops. These knowledge-sharing sessions should be held throughout the course of the project to enable and support both cross-disciplinary and inter-departmental coordination, as well as collaboration among the public sector, private sector and local stakeholders to assess impacts, vulnerabilities and adaptation options.

Stakeholder communication and involvement should include a wide range of participants from central government agencies, all the way through to local communities. The district-level assessment may however be most relevant to national or international stakeholders. They could include national departments, agencies or authorities, funders of government road asset investment projects, as well as other public and private sector stakeholders that have a vested interest in road infrastructure planning and development. Engaging stakeholders who are directly affected by the activities of the project allows for more effective decision making and makes the development process more transparent. The results of the district-level assessment should be used to guide discussions around road adaptation prioritisation with relevant stakeholders.

Recommended actions (by Roads/Transport MDAs)

- Engage on a continuous basis with a wide range of participants to ensure inclusive, effective and efficient stakeholder communication, collaboration and involvement during the work process.
- Include the following stakeholders in ongoing open dialogue:
  - Central government agencies that have a vested interest in road infrastructure planning and development
  - National planning MDA
  - National transport sector stakeholders, including Roads/Transport MDAs
  - Funders of road asset investment projects
  - Multilateral Development Banks (MDBs)
  - Other relevant government ministries/departments (e.g. agriculture, environment, science and relevant technology sectors)
  - Climate change committees
  - Institutes dealing with meteorology/hydrology (e.g. water resources, hydrology and flood control)
  - Emergency services and or the national department dealing with disaster management
  - Relevant businesses and NGOs
  - Local-level stakeholders directly affected by the activities of the project (this should go down all the way to affected village groups)

6.3 Setting of policy, objectives and scope at network level

The setting of policy, objectives and scope was addressed in Chapter 2. The following actions are recommended for driving the embedment of climate change into all activities that fall within the sphere of responsibility of road authorities:

- Appoint a Climate Adaptation Programme Manager for implementation or task a responsible official.
- Coordinate the effects of climate change on a regional basis; their impacts are not restricted by national boundaries. Harmonisation between national and regional road network development activities requires coordination at a high level.
- Secure the likelihood of meeting transport-related objectives by incorporating adaptation considerations into, for example, transport master plans (which may also lead to the identification

of new priorities). The simplest way for a transport plan to incorporate climate change adaptation is to acknowledge the relationship between climate change impacts and the plan's goals, such as safe and effective road networks.

- Align spatial planning policies, national and international technical standards, as well as economic policies and regulations, in support of infrastructure resilience.
- Ensure that asset management policies incorporate climate change adaptation to ensure its practical implementation in such systems.
- Gather policy-driven information, and establish an explicit link between pilot project and policy mainstreaming. Adaptation strategies are tested and evaluated in the context of a given policy sphere and successful measures are fed back into the given policy. This integration can help improve the policy's general direction and achievement of its objectives.
- Integrate adaptation strategies into local comprehensive plans.
- Constrain locations for high-risk infrastructure.
- Develop a programme of training and piloting of the Adaptation Strategy for technical and operational specialists.
- Agree on programmes of vulnerabilities to be progressed to options analysis and action plan development.

7 Concluding remarks

These Change Management Guidelines form part of a set of documents that provide guidance to MDAs in sub-Saharan Africa, and especially to the Roads/Transport MDAs, on how to manage and deal with the impacts of climate change on low-volume road networks.

This Guideline is a supporting document of the *Climate Adaptation Handbook.* It deals with change management within the context of climate adaptation. It covers, inter alia, policy and planning, stakeholder and asset management, and recommendations for the formulation of strategies and programmes for improvement. It provides a broad perspective on a number of issues that can be placed under the heading of change management.

The core theme deals with climate adaptation, and by implication climate science, a domain that Roads/Transport MDAs might not be familiar with. Change management in this respect features various aspects that such institutions may have to deal with in order to incorporate climate change into their systems and operations. These aspects include the following:

- Change management
- Policy
- Climate change science
- Embedment
- Capacity development

To ensure that climate change adaptation is fully addressed and incorporated within the relevant Roads/Transport MDAs, the various aspects listed above would have to be addressed to a larger or lesser extent. The level of detail of information can be improved on in time – it is not necessary to incorporate the fine grain climate change information from the start; it can be an incremental process. A key objective however is to embed climate change information within the planning and management systems of Roads/Transport MDAs so that it forms part of decision-making processes.

Please also consult the *Climate Adaptation Handbook* (Head et al., 2019) as well as *Climate Risk and Vulnerability Assessment Guidelines* (le Roux et al., 2019), the *Engineering Adaptation Guidelines* (Paige-Green et al., 2019a) and the *Visual Assessment Manual* (Paige-Green et al., 2019).

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