

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

Climate Adaptation Handbook



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

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## Abstract

The African Development Bank states that Africa is one of the most vulnerable regions in the world to the impacts of climate change. The majority of both bottom up and top down studies carried out in the region suggest that damages from climate variability and change, relative to population and Gross Domestic Product, will 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, a research programme funded by UK Aid, commissioned a project that started in April 2016 to produce regional guidance on the development of climate-resilient rural access in Africa through research and knowledge sharing within and between participating countries. The output will assist the development of a climate resilient road network that reaches fully into and between rural communities.

The study focusses on: (a) demonstrating appropriate engineering and non-engineering adaptation procedures; (b) sustainable enhancement in the capacity of three AfCAP partner countries; (c) sustainable enhancement in the capacity of additional AfCAP partner countries; and (d) uptake and embedment across AfCAP partner countries.

This Handbook covers part of item (a) and contributes towards (b) and (c) above.

## 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](http://www.research4cap.org)

## Acronyms, Units and Currencies

\$	United States Dollar
°C	Degrees Celsius
AfDB	African Development Bank
ADB	Asian Development Bank
AfCAP	Africa Community Access Partnership
ANE	Administração Nacional de Estradas (National Roads Administration, Mozambique)
AsCAP	Asia Community Access Partnership
CRED	Centre for Research on the Epidemiology of Disasters
CSIR	Council for Scientific and Industrial Research, South Africa
DFID	Department for International Development, UK
EM-DAT	Emergency Events Database
GDP	Gross Domestic Product
GIS	Geographic Information System
MCA	Multi-Criteria Analysis
MDA	Ministries, Departments, Agencies/Authorities
NGO	Non-Governmental Organisation
NPV	Net Present Value
RAI	Rural Access Index
RAMS	Road Asset Management System
ReCAP	Research for Community Access Partnership
SADC	Southern African Development Community
SCS	Soil Conservation Service
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
UNISDR	United Nations International Strategy for Disaster Reconstruction

## Glossary

<b>Adaptation</b>	Autonomous or policy-driven adjustments in practices, processes or structures to take account of changing conditions.
<b>Adaptive Capacity</b>	The degree to which adjustments in practices, processes and structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change [in climate].
<b>Adaptation Needs</b>	The circumstances requiring actions to ensure safety of populations and security of assets in response to climate impacts.
<b>Adaptation Options</b>	The array of strategies and measures that are available and appropriate for addressing adaptation needs. They include a wide range of actions that can be characterised as structural, institutional, or social.
<b>Capacity Building</b>	The ability of enhancing strengths and attributes of, and resources available to, an individual community, society, or organisation to respond to change.
<b>Change Management</b>	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)
<b>Climate Change</b>	Change in the state of the climate that can be identified (e.g. 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. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.
<b>Climate Variability</b>	Variations in the mean state and other statistics of the climate on all spatial and temporal scales beyond those of individual weather elements. Variability may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcing (external variability).
<b>Disaster</b>	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 adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.
<b>Early Warning Systems</b>	The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities, and organisations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss.
<b>Exposure</b>	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.
<b>Extreme Weather Events</b>	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 in 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 not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods.
Hazard	The potential occurrence of a natural or human-induced physical event or trend or physical impact 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. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.
Impacts (Consequences, Outcomes)	Effects on natural and human systems. In this report, the term <i>impacts</i> is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.
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.
Mitigation	The lessening of the potential adverse impacts of physical hazards (including those that are human-induced) through actions that reduce hazard, exposure, and vulnerability.
Resilience	The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard. In this report, the term 'risk' is used primarily to refer to the risks of climate impacts.
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.

Stressors	Events and trends, often not climate-related, that have an important effect on the system exposed and 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 which attempts to identify the root causes for a system's vulnerability [to climate variability and change).

Draft for Comments

## Executive Summary

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

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, evidence of cost, economic and social benefit links to rural communities arising from more resilient rural access will be provided to support wider policy adoption across Africa. It also pays attention to management of measures that could be taken in a scenario when budgets are inadequate or absent.

The study focuses on:

- a) Demonstrating appropriate engineering and non-engineering adaptation procedures;
- b) Sustainable enhancement in the capacity of three AfCAP partner countries<sup>1</sup> (i.e. Ethiopia, Ghana and Mozambique);
- c) Sustainable enhancement in the capacity of additional AfCAP partner countries; and
- d) Uptake and embedment across AfCAP partner countries.

This Handbook addresses the first of these items and provides a methodology for carrying out a climate adaptation assessment for rural access to assist socio-economic development. It also focusses on those activities and actions that conventional standard approaches do not cover. Its use will also improve capacity, Items (b) and (c) above. It is supported by three separate Guideline documents covering the following:

- Change Management<sup>2</sup> (further referred to as the "Change Management Guidelines" in this **Handbook**)
- Climate Threats and Vulnerability Assessment<sup>3</sup> (further referred to as the "Threats and Vulnerability Guidelines" in the **Handbook**)
- Engineering Adaptation<sup>4</sup> (further referred to as the "Engineering Guidelines" in the **Handbook**)

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<sup>1</sup>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.

<sup>2</sup>Head, M and Verhaeghe, B. (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Change Management Guidelines*, GEN2014C. London: ReCAP for DFID.

<sup>3</sup>Le Roux, A; Makhanya, S; Arnold, K and Mwenge Kahinda, J.M. (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Climate Threats and Vulnerability Assessment Guidelines*, GEN2014C. London: ReCAP for DFID.

<sup>4</sup>Paige-Green, P; Verhaeghe, B and Head, M. (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Engineering Adaptation Guidelines*, GEN2014C. London: ReCAP for DFID.

# 1 Introduction to the Handbook

## 1.1 Background

The African Development Bank (AfDB) states that Africa is one of the most vulnerable regions in the world to the impacts of climate change. The majority of both bottom up and top down studies suggest that damages from climate change, relative to population and Gross Domestic Product (GDP), will be higher in Africa than in any other region in the world (AfDB, 2011). Its studies suggest adaptation costs in Africa in the region of \$20-30 billion per annum are required over the next 10 to 20 years.

Sub-Saharan Africa has one of the lowest rural road densities in the world, which is significantly stifling its potential for agricultural growth and development. In addition, less than 40 per cent of rural Africans live within two kilometres of an all-weather road, making socio-economic, medical and educational interventions timely, costly and unreliable. Much of the road network contributing to agricultural and social development in these rural areas can be classified as low volume.

Internationally, Development Partners are substantially increasing their adaptation programmes. Asian Development Bank's total adaptation financing increased from \$558 million in 2011 to \$988 million in 2013, an increase of approximately 77% (ADB, 2011).

## 1.2 Scale of the challenge

Africa has experienced dramatic changes to the continent's climate, which is causing widespread damage to road infrastructure and its associated assets. Rural accessibility is being compromised in a number of countries for increasing proportions of the year, creating both direct and indirect adverse effects on livelihoods and associated socio-economic development.

In the past four decades (1975-2015) African countries have experienced more than 1,400 recorded weather-related disasters (CRED, 2016). These disasters have had significant impacts on affected countries' economies and, in particular, on rural communities and their livelihoods. The impacts of these natural hazards (floods, storms, droughts, extreme temperature, landslides and wildfires) were also felt across all economic sectors and infrastructure. Many communities and countries in Africa are socially and economically vulnerable to extreme climate events. Low adaptive capacity, as well as their high exposure to natural hazards, has resulted in the death of more than 600,000 people (majority due to droughts), left 7.8 million people homeless (99 per cent due to flooding and storms) and affected an estimated 460 million people over the past four decades.

Governments are facing a substantial backlog of damage to existing infrastructure assets caused by the effects of changing climate and are unable to confidently deal with either appropriate design or maintenance of roads. Severe shortages of funds for maintenance has exacerbated the situation.

## 1.3 Aims and Objectives

The overall project aim is to deliver **sustainable enhancement in the capacity of AfCAP partner countries** to reduce current and future climate impacts on vulnerable rural infrastructure. This is to be achieved through the 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** is to identify, characterise and demonstrate appropriate adaptation procedures that may be implemented to strengthen long-term resilience of rural access based on a logical sequence of guidance covering:

- Climate threats
- Climate impacts
- Vulnerability to impact (risk)

- Adequacy of funding
- Non-engineering adaptations (referred to as *Change Management* adaptations here)
- Engineering adaptations
- Prioritisation

The second objective, which focusses on **capacity building and knowledge exchange**, is to meaningfully engage with relevant road and transport Authorities in a knowledge dissemination and capacity-building programme.

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

It also pays attention to the management of measures that could be taken in a scenario when budgets are inadequate or absent. Those activities and actions that conventional standard approaches do not cover are addressed as well.

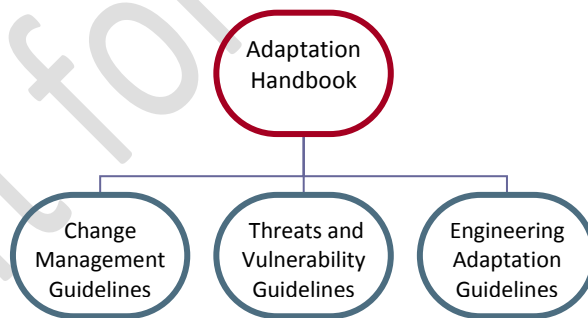
## 2 Components of Handbook

### 2.1 Structure

This Handbook provides relevant information on climate adaptation procedures for rural road access, along with instructions on an appropriate methodology to address climate threats and asset vulnerability, to increase resilience for the foreseeable future. It has been developed to cover a wide range of climatic, geomorphologic and hydrological circumstances commonly applicable to the three study countries, Ethiopia, Ghana and Mozambique, but equally applicable to any of the other Sub-Saharan African countries.

The Handbook is an overarching document and illustrates the fundamental principles, processes and steps required for climate resilience.

Details regarding actual adaptation approaches and measures are included in the accompanying **Guidelines** covering *Change Management*, *Climate Threats and Vulnerability Assessment*, and *Engineering Adaptation*:



The Handbook is 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 Mozambique.

The three countries in which the studies were based represent nearly the full range of climatic systems in Africa. Mozambique is subject to flooding and extreme events, including tropical cyclones. Both Mozambique and Ghana are on the receiving end of water flowing out of major international river basins, and most of their economic activity and population are concentrated along the coast and in low-lying estuaries and deltas. Ethiopia is a land-locked country with smaller river catchments and extensive mountainous areas.

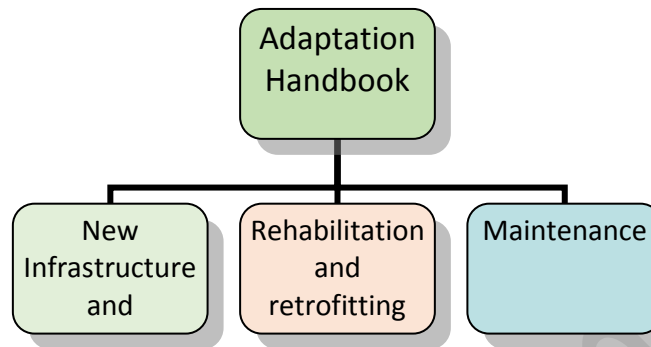
### 2.2 Application

The Handbook has been produced to provide relevant information on adaptive procedures for **new** and **existing** rural access roads, along with instructions on an appropriate methodology to address climate

threats and asset vulnerability and to increase resilience for the foreseeable future. Although produced for *low volume road applications*, most of the principles 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 found in high volume roads and therefore caution is advised.

There are three specific overlapping applications of the Handbook in the context of low volume roads, as shown in Figure 1 below:

**Figure 1 Applications covered in the Handbook**



For the three applications:

- Accessibility objectives are the same but the design and construction processes may be different
- Principles of adaptation methodology remain the same
- Existing infrastructure will have more historical knowledge and understanding of climatic and hydrological impacts
- Maintenance backlog failures of existing roads are the most problematic and the highest priority
- Repair/rehabilitation of assets affected by climate events in order to restore accessibility is not only costly but sometimes results in fruitless expenditure if the restoration measures are not rendered climate resilient.

#### New Infrastructure and structures

It is rare to construct new infrastructure. The limited funding available is mostly used for upgrading, repairs and rehabilitation, except for limited areas of realignment 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 or gravel roads to higher standards (but still low volume roads) together with improvement of existing or construction of new drainage structures. In these cases, a knowledge of the historical performance and hydrology is usually available for the upgrades. Where totally new alignments are planned, information regarding hydrology necessary for the design of structures needs to be acquired, taking into consideration the expected changes in future climate in these areas.

#### Rehabilitation and retrofitting

In cases where the required serviceability criteria can no longer be maintained or where future scenarios are expected to lead to disruption or failure of the infrastructure components, rehabilitation or retrofitting of the existing assets is required. This will also be necessary where the risk levels are considered unacceptable, for example where failure of a structure or a large landslide may lead to loss of life, extended

periods of road closure or costly rehabilitation works. Many of the structures on rural access roads in sub-Saharan Africa are rather old or were designed as interim measures and are particularly susceptible to flooding damage.

Rehabilitation is also required where a structure, embankment or cutting has failed through recent or past extreme climate effects and will need additional measures to ensure future resilience.

These types of activity are, however, usually very costly.

#### Maintenance of existing infrastructure

Many of the problems related to climate susceptibility can be minimised by practical and timely maintenance. In most sub-Saharan countries, there is a significant maintenance backlog resulting from historical climatic events as well as the inability to fund routine maintenance, resulting in parts of the road network being impassable for varying periods during rainy or wet periods. An important part of the adaptation process is to identify these areas and implement measures to build resilience as soon as possible or as funding permits. There will, however, seldom be sufficient funding for robust measures. Prioritisation of the needs in line with defined criteria must therefore be carried out. Details regarding this prioritisation are provided in this manual.

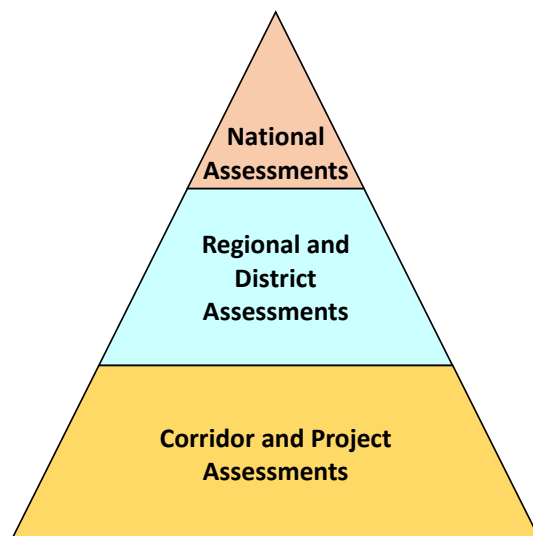
Failure to address the maintenance backlogs will effectively result in a *do-nothing or do-little* scenario, which will require additional planning, emergency and reactive resources following projected increases in extreme events.

#### Actions:

- Determine relevant application(s) and areas of overlap
- Set priority objectives
- Consider budget implications and planning

At a strategic level, it is preferable to develop a national climate threat, vulnerability and adaptation strategy which would support the national climate policies. The results would then inform the next steps through the identification of specific vulnerabilities and locations where more resilient infrastructure is needed. This would 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 levels and strategies should be refined further, with consideration being given to budget implications and planning requirements; see Figure 2.

Figure 2 Cascade principle of strategic assessments to inform policy



### 3 Scope of Handbook

The methodology outlined in this Handbook comprises **five** stages, with each stage consisting of several activities as set out in the table below.

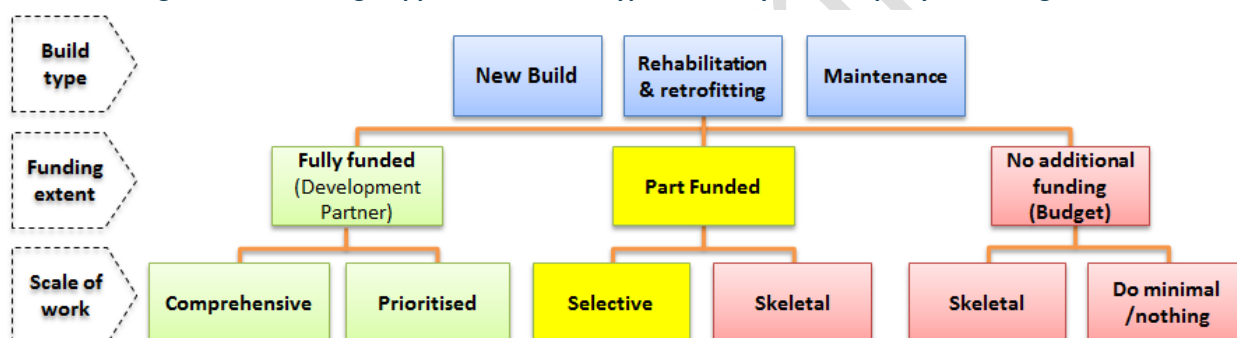
A summary of **PART A: Situational Review and Process Management** is presented in this section with full details contained within the accompanying *Change Management Guidelines*.

**Part B: Methodology** is set out as five Stages, as follows:

<b>Stage 1</b>	<i>Climate risk screening (national/regional)</i>
<b>Stage 2</b>	<i>Impact and vulnerability assessment (project level)</i>
<b>Stage 3</b>	<i>Prioritisation, technical &amp; economical evaluation of options</i>
<b>Stage 4</b>	<i>Project design &amp; implementation</i>
<b>Stage 5</b>	<i>Monitoring &amp; Evaluation</i>

Summary steps and recommended actions are set out in **Part B**, with details contained within the accompanying Guidelines as defined by the colour coding shown in Table 1. The adaptation methodology will be applied in a slightly different rigour depending on the scale, application and availability of funds; see Figure 3.

**Figure 3 Strategic approach based on type of activity and adequacy of funding available**



At one end of the scale is a fully-funded road corridor and at the other is a district maintenance backlog with scarce or zero funds. Policy and strategy directives may be in place or be absent. Appropriate data support systems may or may not be in place, and the level of competence to implement adaptation will vary significantly. Figure 3 illustrates how the strategic approach will vary based on the type of activity and adequacy of funding available. Development Partner funding (in Green) will normally be comprehensive/prioritised whereas part-funded projects will need to be highly selective in their prioritisation and may, by necessity, be skeletal in the activities that can be funded.

Feedback from AfCAP partner countries identifies maintenance as being heavily underfunded or in some cases almost absent and therefore activities will be based on available resources.

This Handbook also pays particular attention to management of measures that could be taken when budgets are inadequate or absent under an *Inadequate Budget Scenario*. It is recommended that, in these circumstances, the guidance set out in Sections 2.2.4 and throughout Section 3 of the Change Management Guidelines are followed under the *Inadequate Budget Scenario*. Doing nothing or very little can result in loss of control, unforeseen problems, possible chaos and potentially loss of life and this approach is not recommended.

This strategic approach is further discussed in Stage 4 of Part B of **this Handbook** (Section B.4: *Project design and implementation*). Further details on how to address poor, inadequate or absent Budget Scenarios are set out in Sections A.5.2, B.3.3 and B.4.1.1.

**Table 1 Contents and scope of the Adaptation Methodology**

<b>PART A</b>	<b>Situational review and process management</b>	<b>Associated Guideline</b>
	Problem identification (including evidence) Identify probable causes Drivers of change (policy driven) Change management Approach and delivery Effective Data management	<b>Change Management</b>
<b>PART B</b>	<b>Methodology</b>	<b>Associated Guideline</b>
<b>Stage 1</b>	<b><i>Climate risk screening (national/regional)</i></b>	
B.1.1	Needs determination	<b>Change Management</b>
B.1.2	Identify and mobilise 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>Threats &amp; Vulnerability</b>
B.1.5	Data gathering and risk analysis	
<b>Stage 2</b>	<b><i>Impact and vulnerability assessment (project level)</i></b>	
B.2.1	Project-level climate risk screening	<b>Threats &amp; Vulnerability</b>
B.2.2	Climate impact assessment	
B.2.3	Data gathering and vulnerability assessment	
<b>Stage 3</b>	<b><i>Technical and economical evaluation of options</i></b>	
B.3.1	Identify strategies and potential adaptation measures	<b>Engineering</b>
B.3.2	Impact assessment of 'do something' and 'do nothing'	
B.3.3	Undertake stakeholder consultations	
B.3.4	Prioritise and select adaptation measures	
<b>Stage 4</b>	<b><i>Project design and implementation</i></b>	
B.4.1	Develop implementation plan (including 'Inadequate budget' scenario)	<b>Engineering</b>
B.4.2	Design parameters and optimisation	
B.4.3	Construction supervision and documentation	
<b>Stage 5</b>	<b><i>Monitoring and Evaluation</i></b>	
B.5.1	Develop monitoring and evaluation plan	<b>Engineering</b>
B.5.2	Report and share implementation experiences	

**KEY:**

Sections covered by the <b><i>Change Management Guidelines</i></b>
Sections Covered by the <b><i>Climate Threats and Vulnerability Assessment Guidelines</i></b>
Sections covered by the <b><i>Engineering Adaptation Guidelines</i></b>

## PART A: Situational Review and Adaptation Management

Adaptation Management options are often referred to as non-engineering options and consist of a range of policy and management improvements. Associated activities of change management that are used to address adaptation for road infrastructure and asset management tend to be more strategic and organisational in their nature than engineering options and **are generally used in conjunction with engineering options in their application**. Engineering climate proofing measures have historically received a greater level of attention. However, the most economically efficient measures may lie beyond engineering measures (such as addressing unsustainable land use practices in an upstream watershed).

### A.1 Reported Problems from Climate Change

African countries tend to be particularly vulnerable to the effects of climate variability, and historical weather-related disasters demonstrate how susceptible these countries are. The following primary climate changes are likely to occur to varying degrees in most parts of sub-Saharan Africa (Le Roux et al, 2016):

- Increased temperatures (average, maximum and number of extremely hot days per year)
- Decreased precipitation and longer drier periods
- Increases in extreme weather events – violent storms, heavy precipitation, heat waves, etc.
- Rising sea-levels
- Migration of the tropical cyclone belt
- Increased wind speeds.

Sections 2.2 to 2.7: *Climate change effects*, **Engineering Guidelines** provide a detailed description of these changes, associated hazards and their effects.

The predominant types of recorded weather-related disasters and the amount of people that have historically been affected are illustrated below. Figure 4 shows dramatic increase in the recorded yearly occurrences of weather related disasters captured in the Emergency Events Database (EM-DAT) between 1975 and 2015 for all African countries (CRED, 2016). The size of the pie charts depicts numbers of people affected relating to the significance of the events. Each chart depicts types of effects – the significance of flooding and drought is particularly noticeable. Also, the additional effects of storms in southern Africa are highlighted.

There is clear evidence that climate change has already affected the magnitude and frequency of climate extremes causing damage to infrastructure and dislocating rural communities. Particularly vulnerable AfCAP partner countries are Ethiopia, Kenya, Mozambique, Ghana, South Sudan, Tanzania and Uganda; however, all African countries are affected to a significant degree.

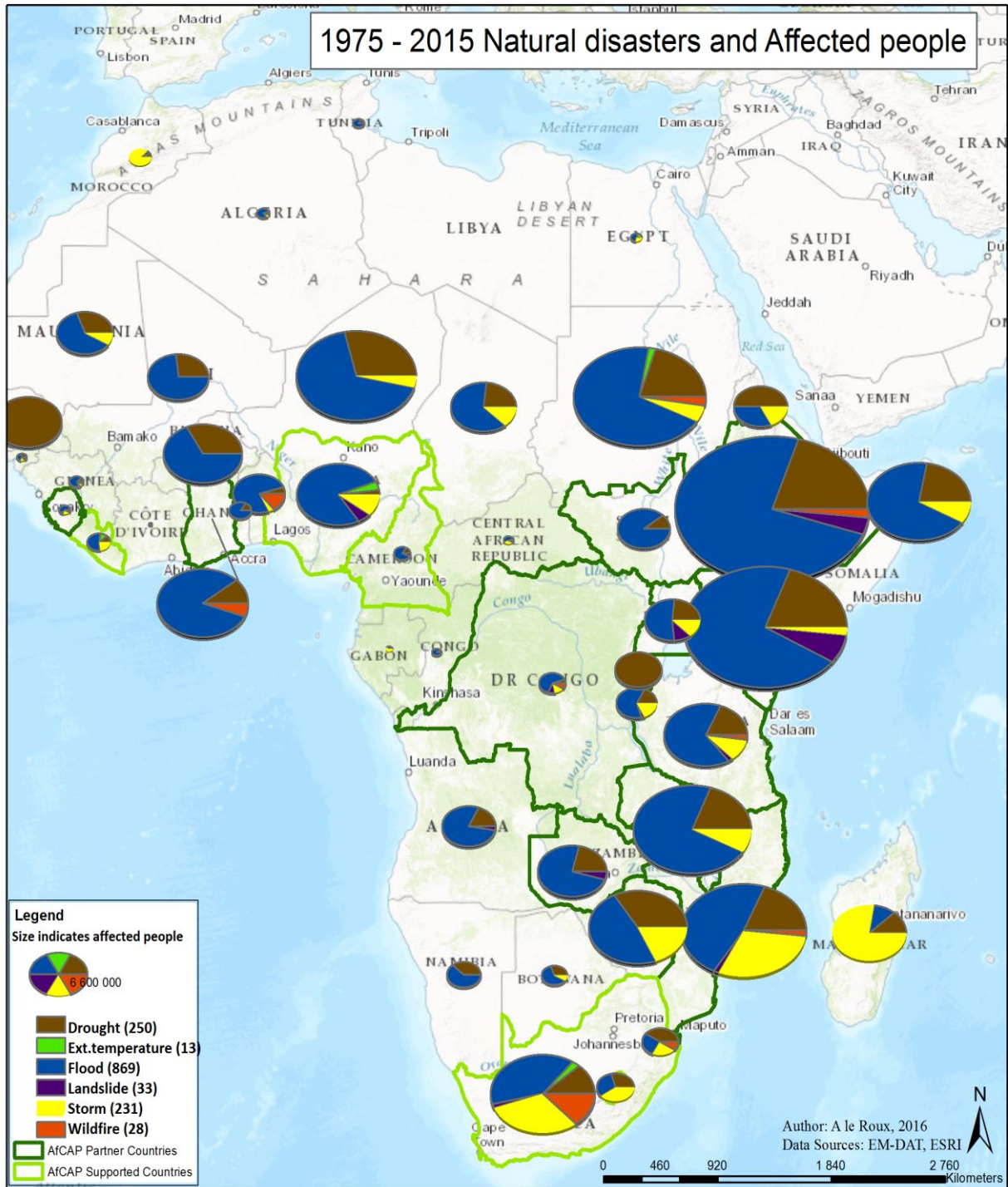
### A.2 Causes and Effects

Figure 5 illustrates the significance of weather-related disasters and number of people affected per year. The number of events, particularly those related to floods and storms, should be noted.

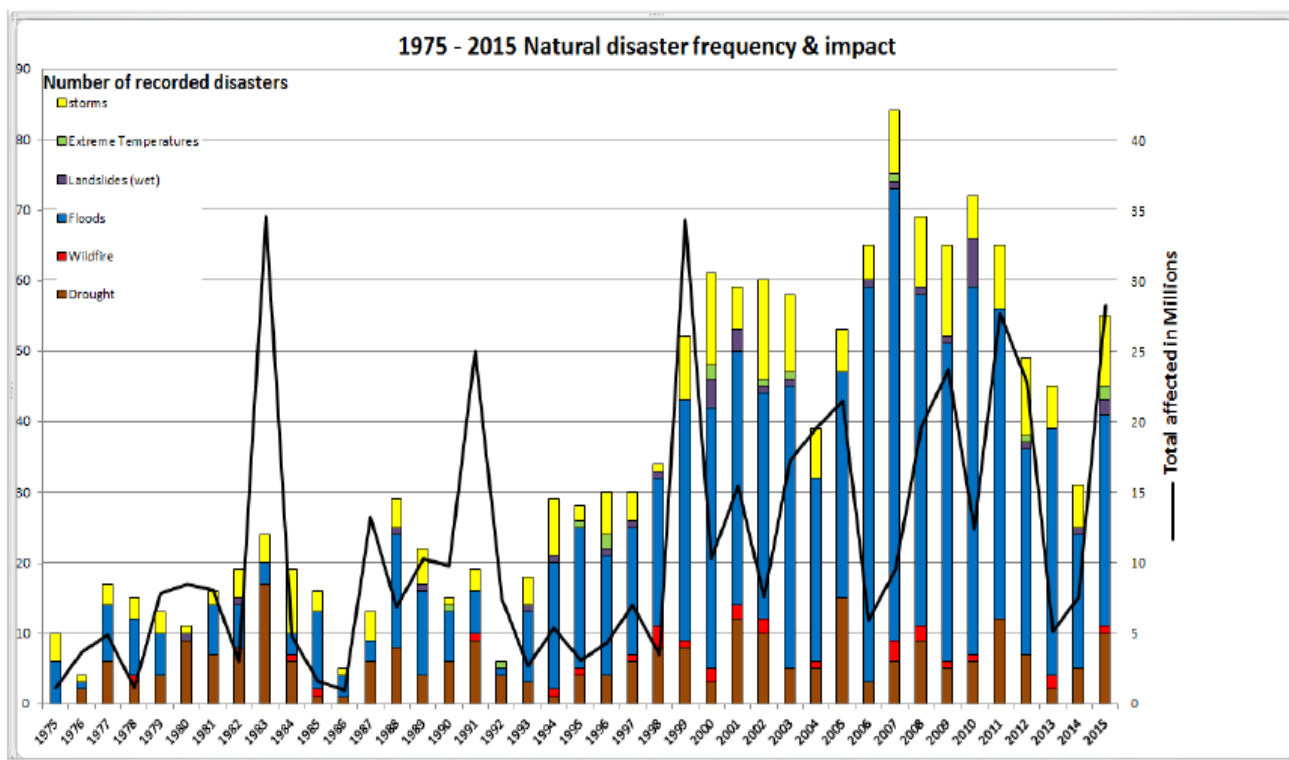
Related secondary effects of climate change could include:

- Changes in intensity and frequency of flooding
- Changed frequency of extreme storm surges
- Changes in the optimum construction season (possibly timing and length) and conditions due to precipitation and temperature constraints
- Increase/reduction in soil moisture
- Changes in groundwater levels
- Changes in ecological equilibrium (i.e. vegetation density and type; rate of growth; longer/shorter growing seasons)

Figure 4 Recorded weather-related disasters and affected populations (Le Roux et al, 2016)



**Figure 5 Occurrence of recorded weather-related disasters and total number of people affected per year from 1975 – 2015 (source data extracted from EM-DAT, 2016)**



### A.2.1 Rural access

Low-volume rural road networks vary from simple tracks and un-engineered earth roads to reasonable, high standard paved roads built to “conventional” standards. Irrespective of their quality, these roads are frequently rendered impassable because of periodic extreme weather events. Associated with these roads are water crossing structures, ranging from drifts/fords to culverts of varying sizes and larger bridges. High water velocities often damage these structures, rendering road links impassable for extended periods. Flooding leads to similar consequences. Whereas road pavements can usually be reinstated quickly to restore rideability after extreme events, road closures caused by flooding may take several days or weeks before water levels subside and accessibility can be restored. However, severe harm to water crossing structures caused by destructive water velocities could take several weeks to months to reinstate, depending on the emergency response capability and adaptive capacity of the road authority.

It has been shown in southern Africa that for low volume road networks (< 1 million cumulative equivalent single standard axle loads over their service life), the environment (mainly climate) plays a much larger role in contributing to deterioration than traffic (SATCC, 2003).

See Section 1.2.2: *Rural access, Engineering Guidelines* for more guidance on this subject.

### A.2.2 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. Problems have been exacerbated by the reluctance of Development Partners to set up maintenance funds within their new construction or rehabilitation programmes. Consequently, significant maintenance backlogs are common-place.

### A.2.3 Inadequate budgets

Capital and maintenance budgets are traditionally insufficient, even when relatively well-managed Road Funds have been established. Poor prioritisation, through inadequate data and management systems, has led to wasteful use of funds (e.g. *firefighting* instead building resilience).

In recent years, increases in extreme weather and unpredictable rainy seasons have created unprecedented backlogs of maintenance and rehabilitation. Emergency funds are often woefully inadequate to address the increasing scale of damage from climate. In the worst cases backlogs cannot be addressed and maintenance programmes are suspended except for routine maintenance. Managing access is particularly challenging in these circumstances, often referred to as Do nothing / Do minimal. This Handbook deals extensively with this particularly prevalent situation, referred to as the Inadequate Budget Scenario. In these circumstances there are specific actions and plans that can be undertaken to reduce the impact of climate events and to manage access through a planned programme of information management, early warning systems, community self-help, emergency planning and stakeholder collaboration.

The **Change Management Guidelines** gives detailed guidance on dealing with a poor, inadequate or absent Budget Scenario in Section 2.3.3: *Inadequate budgets*, Section 2.4.4: *Adaptation management in cases of poor or inadequate budget scenarios*, throughout Section 3: *Change Management*, and Section 4.5: *Do-minimal approach*

### A.2.4 Projected Climate Change over Africa

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 (Le Roux et al, 2016). Moreover, the southern African region and Mediterranean North Africa are likely to become generally drier, whilst East Africa and most of tropical Africa are likely to become wetter. 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. For the southern African region, generally drier conditions and the future frequent occurrence of dry spells are likely over most of the interior. Tropical cyclone tracks are projected to shift northward, bringing more flood events to northern Mozambique and fewer to the Limpopo province in South Africa. 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.

Further details on climate change projections are provided in Section 2.2 of the **Change Management Guidelines**.

## A.3 Drivers for Change

### A.3.1 Policy and plans

Although multisector policies on climate change are being addressed in many countries, policies and strategies specific to the roads and related infrastructure sector are almost absent.

Government and MDA (Ministries, Departments and Agencies/Authorities) policies on climate adaptation set the scope and content for strategic planning for programmes and plans which, when implemented will create more sustainable rural access.

Section 2.4.2: *Policy options for climate adaptation*, **Change Management Guidelines** sets out policy options and provides guidance on how to translate these into strategies and plans

## A.4 Adaptation Management

Adaptation Management has the potential for making significant steps towards creating resilience to climate effects in a cost-effective way. It covers planning, stakeholder and asset management and involves formulation of strategies and programmes for improvement.

### A.4.1 Integrated approach

By implementing an integrated approach, stakeholders can anticipate and mitigate impacts in a more effective way.

Section 3.1 of the Change Management Guidelines sets out all activities and actions necessary to achieve an integrated approach including:

- Identify and mobilise stakeholder and expertise involvement
- Improved network and programme management to anticipate and mitigate impacts
- Improved asset management resilience
- Maintenance planning and early warning
- Environmental management
- Hydrological management
- Augmenting standards and design guides
- Road safety
- Research

### A.4.2 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.

#### A.4.2.1 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.

See Sections 4.3: *Prioritisation of adaptation needs* and 4.4: *Adaptation options in the road sector*, **Engineering Guidelines** for more information.

#### A.4.2.2 Prioritisation of adaptation needs

Indigent people struggle more than others to cope with and adapt to climate change and natural hazards. There is a downward spiral effect when climate affects economic development and creates loss of access at the same time.

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

- Natural disasters push people into poverty and prevent poor people from escaping poverty.
- An increase in natural hazards is already observed and will worsen in the next decades.
- These changes in hazards will affect poor people and our ability to eradicate poverty. Because poor people are often most exposed to natural hazards and lose a greater share of their assets and income when hit by a disaster, natural disasters increase inequality and may contribute toward a decoupling of economic growth and poverty reduction.

The process of prioritisation will require significant input from both road authorities and communities where differing needs and importance may prevail and typically would require decisions of a strategic nature.

See Section 4.3: *Prioritisation of adaptation needs, Engineering Guidelines.*

Typical criteria for prioritisation, set out in Section 3.2.2 in the Change Management Guidelines are:

- Potential loss of life
- Availability of alternative routes
- Cost and consequences of closure
- Environmental/sustainability issues (i.e. pollution, aesthetics, etc.)
- Cost of repair
- Available funds
- Accessibility requirements.

#### A.4.2.3 Serviceability

It is important that all roads are carefully and correctly classified in terms of their **main function** (i.e. provision of mobility or access) and 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.

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

The proposed classifications of Level of Serviceability for roads predominantly providing mobility and for **Accessibility are set out in Section 3.2.2 Prioritisation of Adaptation Needs in the Change Management Guidelines.**

#### A.4.3 Embedment

Embedment covers the preparation of full documentation, the implementation thereof and delivery of the adaptation process. The documentation that would need to account for climate variability and change as part of the adaptation process would include:

- 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.

#### A.4.4 Capacity building

In order to establish and implement climate adaptation successfully, national capacity will need to be developed across all relevant stakeholders. This includes road and transport ministries, departments and agencies/authorities, and will include a wide range of participants from central government agencies cascading all the way through to village groups.

See Section 3.4: *Capacity Building, Change Management Guidelines* for further details.

**Recommended Actions** to be considered for systematic capacity building:

- 1) Engage stakeholders on capacity development
- 2) Assess capacity needs and assets
- 3) Formulate a capacity development response based on:
  - Institutional arrangements – policies, procedures, resource management, organisation, leadership, frameworks, and communication;
  - Leadership – high level involvement will help priority setting, communication and strategic planning;
  - Knowledge – knowledge is the foundation of capacity;
  - Accountability – the implementation of accountability measures facilitates better performance and efficiency.
- 4) Implement a capacity development response
- 5) Evaluate capacity development.

## A.5 Approach and Delivery

### A.5.1 Funding and budgets

Finding the necessary funding to implement climate resilience is going to be one of the biggest challenges for Road Authorities. Funding is already, and has been for many years, insufficient to even maintain the existing infrastructure. Response to current extreme events results in funding being diverted for other sources, usually maintenance budgets, to “emergency” funds exacerbating the already underfunded maintenance requirements.

Until recently, most Development Partners have not implemented robust risk, screening and adaptation methodologies for road infrastructure projects. Experiences are not well developed or documented which has led to cases of insufficient resilience of assets.

Development Partner investment strategies are set out in Section 4.1: *Funding and climate vulnerability screening*, **Change Management Guidelines**; and Considerations for new infrastructure, rehabilitation, retrofitting and maintenance are presented as Sections 4.2 to 4.4 of the **Change Management guidelines**.

### A.5.2 Inadequate budget scenario

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

- **Lack of knowledge:** not familiar with, or inability to understand, the form or scale of the problem
- **Failure to act:** inability to put appropriate measures in place or unwillingness to address the problem
- **Insufficient funds:** either through not appreciating the scale of the problem or inability to secure funding.

Many African governments currently lack the 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 increase costs related to dealing with disruption, loss of access, rehabilitation and socio-economic development. Shocks from unexpected extreme climate events severely undermine community and business resilience.

*Doing nothing* is often the result of insufficient funding. If this path is taken in an unplanned way, it may result in frequent disruptions to the infrastructure network, and will generally take longer and cost significantly more in the long run to restore accessibility. It can also cause prolonged negative effects on socio-economic development.

By necessity, this option is becoming much more prevalent as maintenance backlogs increase and funding becomes more problematic. Unfortunately, if part of a *reactive* management programme it becomes difficult to address prioritisation of affected communities in any meaningful manner.

In many circumstances, there is not enough budget to deal with all affected areas, roads and structures; or that the consequences of climate change are too severe to justify comprehensive physical adaptation. In these circumstances, selection should be on the basis of socio-economic effects and cost-benefit analyses (See Section B.3.4). A planned programme of dialogue with affected communities, well dispersed information and contingency programmes is necessary to minimise the adverse effects of these decisions.

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

A strategic plan for an *Insufficient Budget Scenario* should be prepared in these circumstances, as set out in Section B.3.3.

**Recommended Actions** include:

- Take proactive actions to determine the scale of the problem
- Consult with all relevant stakeholders to agree what type of measures can be funded, if any
- Develop strategic plan for an *Insufficient Budget* scenario
- Develop contingency plans

The subject is covered in more detail in Section B.3.4: *Socio-economic analysis of 'do something' and 'do nothing'*, **Climate Adaptation Handbook**.

### A.5.3 Management of delivery

Funding is the major stumbling block for many African countries in ensuring resilience of the infrastructure in any area. New construction is typically funded by donor partners or aid programmes as was shown in Figure 3. Most development projects are fully funded but some may require additional funding from within the countries' treasury. Rehabilitation/retrofitting may only be partly-funded by outside agencies but is mostly funded by the national treasury (often augmented through dedicated Road Funds). This is likely to be applied selectively to high priority projects with other projects obtaining little or no funding. Maintenance is generally entirely funded from local sources and is inevitably significantly underfunded.

Generally, only selected high-priority projects are fully funded. Rehabilitation and retrofitting may receive part funding for selective high priority programmes and the remainder of the infrastructure network would be subjected to operational budgets that, in many cases, result in *'do nothing'* or *'do little'*.

### A.6 Effective Data and Asset Management

Asset management is an overarching business model that provides the framework upon which climate change initiatives can be readily implemented into a road authority. For climate adaptation, additional information needs to be collected to include assessment of 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 need to be considered as part of the day-to-day business of the road authority.

Described in further detail in Section 2.5, **Threats and Vulnerability Guidelines**, and in Section 5: *Effective Data Management, Change Management Guidelines*.

All available data covering climate change and patterns should be identified and analysed for their usefulness. The same would apply to the inventory of Infrastructure assets and their condition.

All roads should be carefully and correctly classified in terms of their required levels of serviceability as a part of the prioritisation process). This may differ from the existing road classifications, which may be based on traffic counts, demographics or purpose. Since it is not economically possible to address every potential climate resilience problem, it is necessary to prioritise the roads within an area. This 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 analysis (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 condition, to identify any preliminary improvements.

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

Each project will need to be assessed in terms of the costs of adaptation versus the cost of *doing nothing*, considering all the engineering, social and environmental costs and the discounted overall life-cycle costs to allow fair comparisons.

Climate change has the potential to result in a \$3.1 billion impact to roads in Ethiopia when the effects of temperature, precipitation and flooding increases are taken into consideration through to 2100 (World Bank, 2010). These costs could be reduced by 54 per cent if adaptation policies are adopted through policy changes by the government. However, even with these adaptations, the potential cost to Ethiopian roads from climate change could be as high as \$1.4 billion. (Chinowsky et al, 2011)

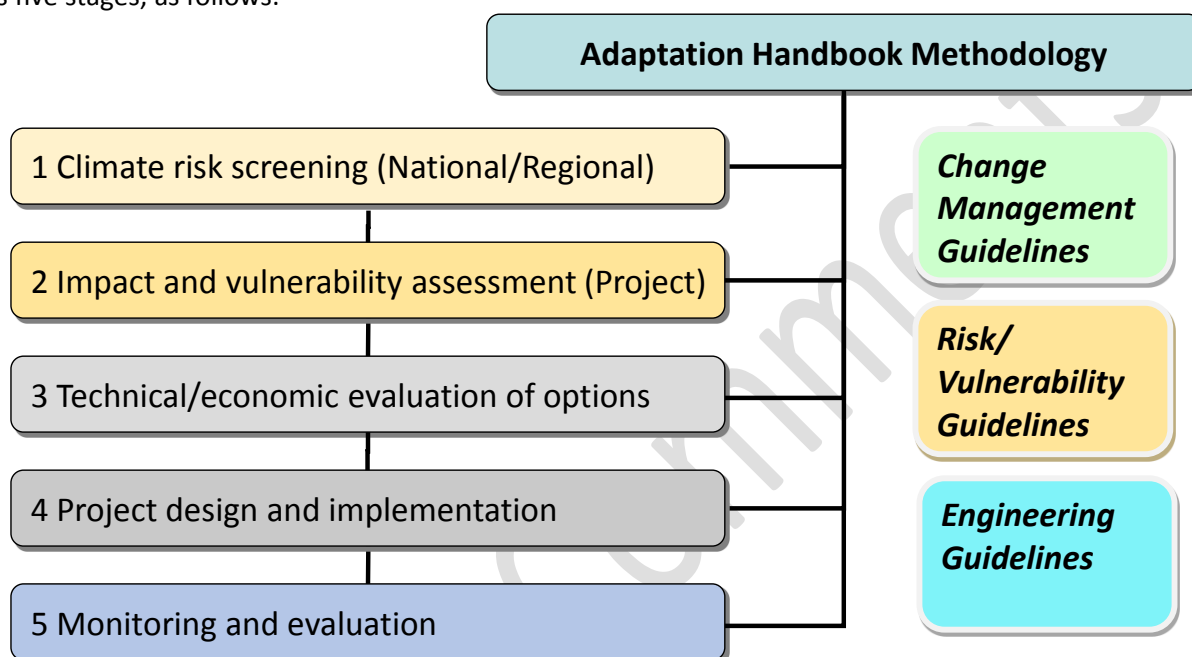
To implement the necessary adaptations to make roads more climate resilient and assist with the prioritisation, it is necessary to carry out visual assessments of existing roads with particular attention being paid to those problems specifically related to climatic effects.

## PART B: Methodology

The Adaptation Methodology identifies risks and vulnerabilities, sets out strategies and options and guides design for implementation and review. Adaptation can be defined as:

*Actions taken by infrastructure stakeholders to avoid, withstand or take advantage of current and projected climate changes and impacts. Adaptation decreases a system's vulnerability, and increases its resilience to impacts.*

It has five stages, as follows:



The Handbook is the overarching document and 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*, *Climate Threats and Vulnerability Assessment* and *Engineering Adaptation*. Within the context of these guidelines, risk is defined as a function of hazards, rural access road exposure and vulnerability in terms of rural community access (le Roux et al, 2016). In particular, the following definitions apply:

- **Hazards:** Climate-related events that can possibly cause damage to and/or interruption of service of rural low volume access road infrastructure as well as potential loss of life (e.g. floods, landslides);
- **Exposure:** Location of low volume road facilities, the associated structures and road environment as well as rural communities in places that could be adversely affected (within the hazard footprint);
- **Vulnerability:** Propensity to be adversely affected, considering the dependence of rural communities on these low volume access roads.

A national threat and vulnerability assessment (“Climate Risk Screening”, *Stage 1*) should be carried out first. Although climate risk screening is of critical importance for national multi-sectorial planning and decision making, it is not necessarily a requirement for the implementation of an adaptation methodology at project level (*Stages 2 to 5*).

The climate risk screening methodology presented in *Stage 1* thus proposes a rural road risk and vulnerability assessment methodology that speaks to national decision makers, whereas *Stages 2 to 5* propose a methodology for a rural access road risk and vulnerability assessment method on a project level and the identification, prioritisation and implementation of adaptation options, and speaks to road construction and engineering professionals.

## B.1 STAGE 1: Climate Risk Screening

A geospatial climate-related road infrastructure risk and vulnerability assessment can provide key geographic information aimed towards supporting decision makers in identifying those roads that should be prioritised for repair, improvement or development in the light of changing climatic conditions.

The level of detail and decision support provided by a risk and vulnerability assessment is highly dependent on the question and scale of the study. At a national scale, a climate vulnerability, threat and adaptation strategy provides strategic level support for national road and climate policies. At finer scales, regional and district level analysis play a vital role in informing future planning and development decisions by prioritising high risk areas, while local scale analyses provide highly detailed project level assessments that support project managers while adapting individual stretches of road or road corridors.

### B.1.1 Needs determination

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

- Climate Adaptation is often being addressed as part of a multi-sectoral national approach, but transport and roads are not currently being included in any meaningful way.
- Climate risks and vulnerabilities need to be addressed.
- Relevant climate-related data needs to be collected to support a new approach.
- Appropriate new policies and strategies need to be embedded in all programmes.
- Road damage backlogs from climatic effects are increasing at an alarming rate and need appropriate guidance to be addressed.
- Maintenance budgets for capital works and maintenance are not adequate to deal effectively with climate effects.
- Lack of funding is so acute in many countries that specific scenarios for addressing challenges with poor, inadequate or absent funding are required.
- Knowledge and capacity on climate adaptation need strengthening.

#### Recommended Actions:

- Carry out needs analyses within the roads and transport sector to identify the scope of the activities to be carried out and the outputs needed
- Consult with all relevant stakeholders so as to establish clear communication and cooperation lines.

### B.1.2 Identify and mobilise stakeholder/partner involvement

Stakeholder communication and involvement should be ongoing throughout the assessment process, and facilitated through collaborative work sessions and workshops. These knowledge sharing sessions should be held throughout to enable and support both cross-disciplinary and inter-departmental coordination and 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 national/regional-level assessment may, however, be most relevant to national or international stakeholders such as 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.

It is **recommended** that continuous engagement with a wide range of participants be held to ensure effective and efficient stakeholder communication, collaboration and involvement during the work process. The following stakeholders should be included in ongoing open dialogue:

- Central government agencies that have a vested interest in road infrastructure planning and development
- National planning departments
- National transport sector stakeholders, including road and transport ministries, departments and agencies/authorities (MDA's)
- Funders of road asset investment projects
- 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
- Local level stakeholders directly affected by the activities of the project (this should go down all the way to affected village groups)

Where poor, inadequate or absent funding scenarios exist, the following stakeholders should also be consulted:

- Local communities and businesses
- Local schools, clinics, hospitals,
- Farmers and traders
- Charitable organisations
- NGO's

### **B.1.3 Setting of policy, objectives and scope (network level)**

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

- The extent to which the policy, strategy, regulation, or plan under consideration could be vulnerable to risks arising from climate variability and change
- The extent to which climate change risks have been taken into consideration in the course of programme formulation
- The extent to which the policy, strategy, regulation or plan could lead to increased vulnerability, leading to maladaptation or, conversely, to missing important opportunities arising from climate change; and
- Pre-existing policies, strategies, regulations, or plans that are being revised, what amendments might be warranted in order to address climate risks and opportunities.

#### **Recommended Actions:**

- Appoint a Climate Adaptation Programme Manager for implementation
- Climate change impacts are not set by national boundaries; their effects require regional coordination. Harmonisation between national and regional road network development activities requires coordination at a high level.
- Incorporating adaptation considerations into, for example, transport master plans will further secure the likelihood of meeting transport-related objectives and may also identify 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, and economic policies and regulation in support of infrastructure resilience.

- Policy-driven information gathering, or 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 up 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 programmes of vulnerabilities to be progressed to options analysis and action plan development.

#### B.1.4 Analysis of observed and projected climate effects

The observed climate impacts for AfCAP partner countries were shown in Figure 4: *Recorded weather-related disasters and affected populations* and Figure 5: *Occurrence of recorded weather-related disasters and total number of people affected per year from 1975 – 2015* (cf. Section A.1). Source data can be extracted from the Emergency Events Database (EM-DAT; <https://www.emdat.be/database>).

District level risk and vulnerability assessments are needed to facilitate identification of districts where roads are most vulnerable to a changing climate in terms of the impact on rural accessibility. This is done broadly using existing road network and road design principles to determine where roads could potentially be most affected by changes in climate and socio-economic patterns and in more detail based on the visual assessments of vulnerability. The output of the district level assessment identifies potential high-risk areas (areas that should be prioritised for road adaptation). These results can then be used to determine where in-depth local level road risk and vulnerability assessments would be most beneficial.

The recommendations presented in this section are based on methodologies that have been applied and tested in three AfCAP African countries, namely Ethiopia, Ghana and Mozambique.

#### Main projected changes in climate (2071-2100) for AfCAP countries:

##### **Zambia**

Drastic temperature increases are projected over Zambia under low mitigation – exceeding 6°C over the western parts towards the end of the century. The western part of the country is also likely to become generally drier with a decrease in extreme rainfall events. However, over the far north-eastern parts, increases in rainfall and extreme rainfall events are likely.

##### **Mozambique**

General increases in rainfall totals, extreme rainfall events and the landfall of tropical cyclones are likely over Northern Mozambique under climate change. Over the southern parts, including the Limpopo river basin region, rainfall decreases are likely (it should be noted though, that some climate models extend the region of wetter conditions under climate change to southern Mozambique). The projected changes in maximum temperature are smaller than over the southern interior to the west, but may still exceed 4°C.

##### **Malawi**

Malawi is located in a region that is considered marginal in terms of its projected change in rainfall. It is located between a large part of the southern African interior projected to become generally drier, and a large part of East Africa (from northern Mozambique in the south to the Horn of Africa) that is projected to become generally wetter. As a result, some uncertainty surrounds the projected rainfall signal for Malawi, with some models projecting general rainfall increases and more extreme rainfall events, but with other models projecting the opposite signal. The projected changes in maximum temperature are smaller than in the subtropics, but may still exceed 4°C for the scenario where the country also becomes generally drier.

### **Kenya, Tanzania and Uganda**

General rainfall increases are projected over East Africa under climate change by most climate models, including over the Kenyan, Tanzanian and Ugandan region. Increases in extreme rainfall events are consistently projected. The projected changes in maximum temperature are smaller than in the subtropics, but may still exceed 4°C.

### **Ethiopia**

General rainfall increases are projected over the Horn of Africa under climate change by most climate models, including over the eastern parts of Ethiopia. Over the western highland regions decreases in rainfall are likely. Increases in extreme rainfall events are consistently projected. The projected changes in maximum temperature are smaller than further to the north, but may still be as high as 4°C.

### **South Sudan**

General decreases in rainfall, with associated increases in extreme rainfall events, are projected by most climate models for South Sudan under climate change. However, a minority of climate models indicate that a generally drier future with a decrease in extreme events is also likely. The projected changes in temperature are smaller than over North Africa to the west, but may still exceed 4°C.

### **Democratic Republic of Congo (DRC)**

General increases in rainfall and extreme rainfall are likely over much of the African tropics, including the DRC. Temperature increases may be as high as 4°C.

### **Ghana, Liberia and Sierra Leone**

Ghana, Liberia and Sierra Leone are in a part of West Africa for which climate models are projecting very diverse rainfall futures, ranging from significantly wetter with more extreme events, to significantly drier with fewer extreme events. Temperature increases may well exceed 4°C.

The methodology for undertaking a risk and vulnerability assessment at district level consists of four phases, each containing a number of action steps:

#### **Phase 1: Identify threats affecting the vulnerability of roads**

- *Step 1.1:* Identify current threats affecting the vulnerability of roads (based on historical data)
- *Step 1.2:* Understand future threats that will likely affect the vulnerability of roads (based on projected climate data)

#### **Phase 2: Data collection and preparation**

- *Step 2.1:* Data collection
  - What data to collect?
  - Where to collect data?
- *Step 2.2:* Data preparation

#### **Phase 3: Data Analysis**

- *Step 3.1:* Determine road exposure to identified threats
- *Step 3.2:* Determine road criticality (based on rural accessibility and remoteness)
- *Step 3.3:* Determine most vulnerable regions/districts
  - Most vulnerable regions/districts under current climate and socio-economic conditions
  - Future vulnerable regions/districts under a changing climate and growing population

#### **Phase 4: Embedment in Road Asset Management System**

- *Step 4.1:* Consider which climate threat indicators to include in RAMS
- *Step 4.2:* Export data to RAMS
- *Step 4.3:* Analyse data in RAMS

#### **Phase 5: Adaptation** (cf. *Change Management and Engineering Adaptation* guidelines)

See Section 3.2: *Piloting a district-level risk and vulnerability assessment*, **Threats and Vulnerability Guidelines** for full explanation.

The aim of identifying threats affecting vulnerability of roads is twofold; *firstly*, to analyse historical climate data in order to identify the current climate threats that most affect the vulnerability of roads, and *secondly*, to use the identified current climate threats to inform an investigation into the future hazards that will likely affect the vulnerability of roads under projected climate change conditions.

**Recommended Actions:**

- To formulate a national climate threat picture, documents, data and statistics from country level assessments indicating the type, frequency and intensity of historical climate induced disasters should be sourced.
- The investigation into historical climate data archives, country level assessment reports and knowledge sharing workshops inform the process of identifying the climate threats most affecting the vulnerability of roads. From this enquiry, the driving forces of vulnerability should be identified, and flagged for further analyses in this assessment process.
- Flood hazards have the greatest impact on rural road infrastructure, where a 100-year flood can be assumed to damage up to 30 and 10 per cent of unpaved and paved roads respectively (Chinowsky et al, 2012).
- Two main types of climate-related impacts should be considered for rural roads. These are water-related hazards (inundation by flooding and landslides) as a result of rainfall extremes, and road degradation as a result of incremental changes in average rainfall and temperature.
- Other common climatic induced threats that may be considered include storms, droughts, windiness and wildfires if determined to be of high frequency, magnitude and extent.
- The results of the climate threat investigation should be mapped.

The following climate parameters and data can be assessed to determine climate threats:

- Sea level and wave action (for coastal roads)
- Precipitation intensity and slope of ground (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)

It is also important to understand how climate threats are projected to change into the mid- (2050) to long-term (2100) future. This is done by conducting forward looking scenario studies using climate models and projected data.

**Recommended Actions:**

- The results of current threats should inform the starting point for conducting forward looking investigations
- Use mid-term (2021-2050) future projections which are generally more accurate than long-term (2070-2100).
- Future climate assessments should ideally be the result of high resolution physical climate change modelling outputs; these should include: Projected changes in climate with regard to temperature and rainfall including changes in extreme events and, where applicable, projected changes in sea level rise and wind velocity in coastal environments
- The results of the future climate threat investigation should be mapped.

### **B.1.5 Data gathering and risk analysis**

A range of data should be sourced as input that supports the risk and vulnerability analyses. As a starting point, road network data, climate threat data and socio-economic data need to be sourced from national authorities and/or open source repositories. Datasets that support analysis, such as district boundary data

and town hierarchy data also need to be sourced. Data to support the district level risk and vulnerability analyses should, ideally, be sourced from relevant country specific national authorities who have been appointed as data custodians.

Once data has been sourced, data preparation should be done to transform data from its original state into variables for rural road specific hazard assessment.

Table 2 outlines the possible data required to perform a district-level risk and vulnerability analysis, together with suggested national authorities responsible for maintaining specific custodian data, or, in the absence of such data, open source data repositories where data can be sourced freely.

The first step of the risk analysis is to conduct a **road exposure and vulnerability assessment** by determining which districts are most at risk to climate hazard threats, and in what condition the roads and structures in these districts are. This information can then be used to determine road exposure vulnerability, where roads and/or structures in poor condition located in districts exposed to severe climate threats are more at-risk.

<b>Recommended Actions:</b>	
<ul style="list-style-type: none"> <li>▪ Determine districts most impacted by historical climate threats; e.g. aggregate the number of climate threat events (e.g. severe flooding events in past four decades) per district.</li> <li>▪ Overlay road network condition data with districts most impacted by climate threats</li> <li>▪ Finally, the results of the road exposure to identified threats (based on road network conditions (resilience) and exposure to climate threats) should be mapped.</li> </ul>	

**Table 2 Suggested data required to perform a district-level risk and vulnerability analysis and possible data sources**

<b>Methodology</b>	<b>Data Type</b>	<b>Possible national authorities (country specific)</b>	<b>Open source data repositories</b>
Road network	National road network	<ul style="list-style-type: none"> <li>• National road agency authority</li> <li>• National road asset management system</li> </ul>	<ul style="list-style-type: none"> <li>• Diva-GIS</li> </ul>
Climate Threat	Historical climate data (National Scale)	<ul style="list-style-type: none"> <li>• National disaster management department</li> <li>• National meteorological department</li> </ul>	<ul style="list-style-type: none"> <li>• EM-DAT</li> <li>• ERA-Interim</li> <li>• CRUTEMP4v</li> </ul>
	Specific hazard data for main identified climate threats (e.g. Flood history) (District Scale)	<ul style="list-style-type: none"> <li>• National disaster management department</li> <li>• National meteorological department</li> <li>• National environmental department</li> </ul>	<ul style="list-style-type: none"> <li>• Dartmouth Flood Observatory</li> </ul>
	Projected climate change data (preferably as fine as 8km resolution in the horizontal)		<ul style="list-style-type: none"> <li>• ACCESS1-0</li> <li>• CNRM-CM5</li> </ul>
Socio-Economic	Population data	<ul style="list-style-type: none"> <li>• National statistical service</li> <li>• National census authority</li> </ul>	<ul style="list-style-type: none"> <li>• Worldpop</li> </ul>
	Hierarchy of settlements	<ul style="list-style-type: none"> <li>• Surveyor general office</li> </ul>	<ul style="list-style-type: none"> <li>• Diva-GIS</li> </ul>
	Population projections	<ul style="list-style-type: none"> <li>• National statistical service</li> </ul>	<ul style="list-style-type: none"> <li>• UN ESA</li> </ul>
Analysis Supporting Data	District boundaries	<ul style="list-style-type: none"> <li>• Surveyor general office</li> </ul>	<ul style="list-style-type: none"> <li>• Diva-GIS</li> </ul>
	Satellite images	<ul style="list-style-type: none"> <li>• National space agency</li> </ul>	<ul style="list-style-type: none"> <li>• Landsat (USGS EROS)</li> <li>• ESRI</li> </ul>

Secondly, determine road criticality in terms of rural accessibility. At district level, a criticality assessment is used to evaluate the importance of rural access roads to the communities (districts) they serve (e.g. number of people a road serves and/or number of people without access). To allow the criticality assessment to have a region-specific focus, it is considered as an annex to the road asset vulnerability index. Road exposure and vulnerability are considered as one dimension in the criticality assessment, while other dimensions include road capacity and function.

Rural Access Index (RAI) was developed by the World Bank and measures the rural population who live within 2 km (20-25 minutes of walking time) from an access road as a proportion of the total rural population (Roberts et al., 2004). Some of the factors to be considered in a rural access index:

- Population distribution and density
- Road network density (coverage)
- Population within 2km of an access road
- Population without road access (in terms of both number of people and percentage of population)
- Availability of alternative routes.

#### **Recommended Actions:**

- Calculate rural access index and/or a remoteness indicator (see Section 3.2: Threats and Vulnerability Guidelines)
- A consolidated view of asset criticality per district is formed by aggregating the road exposure and vulnerability index and the rural access index, and this can be mapped.
- The importance of weighting in the aggregation step depends on the need to accommodate preferential information. Country specific multi-criteria analysis is a useful tool to evaluate overall rural access road risk given different views on the importance of the various components.
- Finally, the results of the road criticality analysis depicting the most isolated districts should be mapped.

Sub-sets of data should be aggregated to produce supplementary maps for determination of most vulnerable districts, and therefore road networks. Such maps should include:

- Most vulnerable districts under current climate and socio-economic conditions
- Future vulnerable districts under a changing climate and growing population

A full list of indicators that are relevant for an indicator-based vulnerability assessment is set out as Table 4 in Section 3.3: *Summary of proposed indicators*, **Threats and Vulnerability Guidelines**.

## **B.2 STAGE 2: Impact and Vulnerability Assessment (Project Level)**

### **B.2.1 Project level climate risk screenings**

During the design of new infrastructure, climatic impacts should be determined and included as part of the Environmental Impact Assessment or Strategic Environmental Assessment and should thus be considered in the design, which data should be used to incorporate the necessary adaptation measures. This is particularly relevant to large structures, which would normally have a design life extending into the next century. The structural engineers must be aware of the specific future climate threats (more extreme events, higher temperatures, etc.) and consider these in the design.

For existing roads, however, during (or parallel with) the routine visual assessment of roads for input into Road Asset Management Systems (RAMS), it will be essential to include an assessment of the vulnerability of the road and associated structures (bridges, culverts, embankments, slopes, etc.) to variability and changes in the climate. Potential vulnerabilities and their mitigation will need to be identified. Guidelines for this have been prepared (Visual Assessment Manual for Climate Vulnerability) in conjunction with the existing visual assessment manuals for the Asset Management System to assist assessors with these

cf. Section 5.1: *Hazards, exposure and vulnerability*, **Engineering Guidelines**

decisions. Unlike the prioritisation process, the vulnerability assessment would be a more tactical operation. The climate sensitivity of all components of the road infrastructure needs to be identified in terms of damage and collapse during routine road condition assessments. To minimise the cost of acquiring data on the climate vulnerability of assets, vulnerability assessments should be carried out simultaneously with routine road condition assessments and all necessary data elements should be captured. Although this involves additional training of the assessors, it is possible that the work can be done simultaneously.

### B.2.2 Climate impact assessments

The purpose of conducting a local road vulnerability assessment is to identify specific threats that currently affect a particular road segment and to assess how likely such threats would intensify or reduce in future. Particular threats include erosion of embankments, flooding of road surfaces, loss of road structure integrity, loss of pavement integrity, etc. (Falemo et al, 2015). The intention is that the outputs of the local assessment can be used in the following ways:

- Inform engineering design decisions for the chosen road segments;
- Provide a good understanding of the underlying problems, which is necessary for selection of appropriate adaptation measures;
- Identification of additional data for inclusion in RAMS
- Identify contextual factors that aggravate the effects of climate on roads, and which can effectively be managed through changes in practices at community, professional or business, or at policy level.

The local assessment follows a four phase process similar in concept to the district vulnerability assessment. The differences between the district and local assessment are in the detail of each step. The local assessment framework consists of the following phases, each with a number of action:

#### Phase 1: Source and prepare data on climate threats on rural roads within a district

- *Step 1.1:* Data sourcing (spatial databases, resilience field assessment data from RAMS)
- *Step 2.2:* Data preparation (including digitization of field data into spatial data format)

#### Phase 2: Road exposure and vulnerability assessment

- *Step 2.1:* Identify hazards that impact roads within a particular district for the current and future climate scenarios
  - Under current climate and environmental conditions
  - Under future climate and environmental conditions
- *Step 2.2:* Determine road exposure and vulnerability to specific climate threats under current and under future climate and environmental conditions
- *Step 2.3:* Evaluate the criticality of the road based on rural accessibility and remoteness
  - Under current socio-economic conditions
  - Under a changing climate and socio-economic conditions

#### Phase 3: Communication and embedment in RAMS

- *Step 3.1:* Prepare and export data to RAMS
- *Step 3.2:* Stakeholder communication about the current and future states of the road network

#### Phase 4: Adaptation

- Providing inputs for road adaptation according to prioritisation

See Section 4.3: *Methods for local assessment of road vulnerability to climate threats, Threats and Vulnerability Guidelines* for full explanation.

The method proposed for local-level climate impact and vulnerability assessment relies on micro-level assessment data in addition to data extracted from national and international spatial databases. The micro-level assessment in this case refers to the field (or road) surveys conducted periodically by local/district road engineers for reporting on road reserve conditions. In the case of climate adaptation, data on resilience aspects are also collected. These include observations on environmental conditions outside of the road reserve including identifying pathways of surface runoff, extreme weather events or disaster incidences. The latter activity can be enhanced by employing **community participatory mapping** tools,

which consist of techniques that consider local inhabitants as repositories of expert knowledge of the environment which can be captured within a geographical framework.

The sub-regional or local road authorities and communities are therefore key stakeholders for a local-level climate risk and vulnerability assessment for roads. The involvement of communities in data collection is crucial. It is also crucial that they understand factors that render roads in their community vulnerable to climate.

**General remarks:**

- If a district-level assessment was done prior to the local assessment, then GIS layers for that district on current and future hazards that were identified can be extracted. However, in a district-level assessment some hazards that directly affect particular roads within a district are likely to be missed in country-specific departmental reports and databases that are main sources. Therefore, hazards that affect that particular road environment (e.g. erosion of embankments, flooding of road surface, loss of road structure integrity, loss of pavement integrity, landslides, etc.) also need to be identified using data from district road authorities and local government departments.
- In the event that a district-level assessment was not conducted prior to the local assessment, then data for a particular district can be extracted from global, departmental and country specific databases in addition to district specific data sources.

### B.2.3 Data gathering and vulnerability assessments

A range of data should be sourced as input that supports the vulnerability assessment including climate threats data, environmental data, road network data and socio-economic data, and local road authorities and government departments would be the custodians of local spatial data on these categories. Additionally, data from the road/project site are vitally important in a local level analysis. These would be ideally extracted from the RAMS. In the case that field assessment data are not warehoused in a RAMS as spatial data, there will be an additional step of digitizing the data spatially.

Once data has been sourced, data preparation should be done to transform data from its original state into variables for rural road specific vulnerability assessment. Vector data should be converted into the raster format to enable raster calculations to assess vulnerability to each threat. In the local assessment vulnerability to specific threats are considered separately, which is different to the district assessment where districts were given a single overall vulnerability score based on the combination of all threats. For example, the road's vulnerability to erosion of embankments and foundations is considered separately from the vulnerability to surface flooding.

The vulnerability index of each segment of the individual roads (usually 100 m long) should be calculated. This is a composite value varying between 0 and 100 consisting of the sum of weighted combinations of the degree and extent of the vulnerable issues, determined during the vulnerability visual assessments. This allows the mathematical prioritisation of vulnerabilities along the road on a consistent and repeatable basis.

Assessment of rural road vulnerability to the following threats is considered:

- Flooding of road surface
- Erosion of embankments and foundations
- Deformations
- Loss of pavement integrity (cracking and aggregate loss)
- Failure of drainage structures

**General remarks:**

At the local scale, the impacts of climate changes cannot be assessed in isolation. The environmental conditions need to be considered using the environmental variables. The following parameters can be assessed to determine the greatest climate-related threats:

- Distance to the coast for coastal roads because of the risk posed by rising sea levels and wave heights exceeding particular thresholds
- The combination of precipitation intensity and slope angle for mountainous regions
- For the design of drainage infrastructure, the combination of water course maps, topography, previous flood extent, road infrastructure location and land cover are important to consider when assessing peak and moderate to heavy long duration rainfall events
- Profiles of past extreme temperature events and droughts in combination with soil and land cover maps are useful in assessing erosion and loss of road surface structure or integrity as vulnerability factors
- Changes to the onset of rainy seasons considered as a threat for road maintenance and construction scheduling
- Deforestation and land cover change in general for landslide risk
- Increase in vegetation cover as a modifying factor in flooding

Data analysis provides insights about sections of the road prone to different threats, such as waterlogging and flood inundation, erosion, landslides and loss of surface materials. An important analysis consideration is the history of climate hazards that have had impacts on particular road segments within a road network. In the local assessment this information is considered as weights to accommodate the possibility that in some areas local disaster information may be difficult to obtain.

**General remarks:**

- Data on expected future climate conditions are used to determine how the identified local level hazards are likely to change under climate change scenarios.
- Assessment requires future climate information as input which ideally should be the result of regional downscaling models from Global Climate Change models, the same data as used in the district-level assessment.
- The choice of the mid-term projection period (2021-2050) is based on practical terms for population and economic outlook and the lifespan of roads.

Calibrating historical hazard weights will rely on combining historical disaster data with other environmental data such as land cover, topography and soil types. For quantification of flood hazards, a hydrological model (Catchment hydrological model) can be implemented if the required data and modelling expertise are available. This model would be implemented outside the GIS environment; however the results would be fed-back into a GIS environment for visualization and further analysis. The weights for the future scenario would be calibrated by considering how hazards profiles (spatial extent, intensity and frequency) as identified in the current situation analysis are likely to change given projected changes in climate and socio-economic conditions.

**Remarks on hydrological modelling:**

- The aim of the hydrological model at catchment level for the local assessment is to properly assess the effects of floods for a specific road. Flood frequency analysis is critical in project level risk and vulnerability analysis, given the socioeconomic and environmental impacts of floods.
- In gauged basin with appropriate observed flows, in both length and quality, design flood estimation may be performed by a frequency analysis. The result of such an analysis is a return period (recurrence interval or repeat interval), which is an estimate of the likelihood of an event, such as a flood or a river discharge flow to occur (ASCE, 1996; Peres and Cancelliere, 2016).
- It is a statistical measurement typically based on historic data denoting the average recurrence interval over an extended period of time, and is usually used for risk analysis (e.g. to decide whether a project

should be allowed to go forward in a zone of a certain risk, or to design structures to withstand an event with a certain return period).

- Recent work in various countries has shown that return periods are likely to change significantly and this should be considered during drainage and structure designs.
- However, for most catchments, which are ungauged, various countries have developed standard techniques for flood estimation ranging from statistical analysis of observed peak discharges and event modelling using rainfall-runoff techniques.
- Traditional approaches comprise empirical formulae, at-site or regional flood frequency analyses, design event models (Rational, Unit Hydrograph and Soil Conservation service (SCS)), etc.

Next a road exposure and vulnerability assessment to specific climate threats is undertaken (see **Step 2.2: Determine road exposure to identified threats**). Information on variability of vulnerability to specific threats along the road help in deciding where to implement specific engineering adaptation options and where there needs to be changes in practice to reduce the damage when adverse climate events occur.

An example of a scoring framework for vulnerability to flooding of the road surface based on some climate, environmental and road structure related factors that have an effect on vulnerability is set out in Table 7 in Section 4.3.1: *Implementing the local level road vulnerability assessment framework*, **Threats and Vulnerability Guidelines**.

#### Remarks on road exposure and vulnerability assessment:

- The road is assessed for vulnerability to specific climate threats and the quantities used to rate vulnerability are determined using scoring frameworks applicable for each threat (see example in Table 7 of Section 4.3.1 of the *Threats and Vulnerability Guidelines*).
- The sourced data need to be transformed into variables that can be reclassified and scored in terms of their effect on vulnerability as follows: 'Substantially increases vulnerability' (+2), 'Increased vulnerability' (+1), 'Does not increase vulnerability' (0)
- The grading on the framework, should be formulated by road engineering experts.
- There are vulnerability factors proposed for consideration in assessing all threats. These concern the age of the road infrastructure, whether the road adheres to design standards and the level of implementation of maintenance procedures.
- Variable preparation would include reclassification of rasters into vulnerability scores to enable calculation of vulnerability to a specific threat.

Lastly **road criticality** (in terms of the importance of that particular road for accessibility to markets and public facilities) is analysed (see **Step 2.3: Determine road criticality**). At the local scale this information would not be mapped but would rather be a narrative provided by that community on what their use of that particular road is to put into perspective the losses incurred by the community when access is interrupted due to climate events.

#### Remarks on road criticality assessment:

- Narrative on typical distances community members have to walk to access the road would be useful.
- Insight into the alternatives they use to get to markets and other important destinations such as schools and clinics when the road cannot be used is also important.
- A consolidated view of the criticality of that road emerges when also considering its exposure to the various threats and how these may change in the future.

- These qualitative insights are useful in justifying investments into climate adaptation and over time development gains by the community as a result of road improvements can be evaluated by returning to interview the community.

Using GIS makes the management of all the input and output data efficient, as well as enables easier communication with stakeholders through maps. Data can also be easily shared for further evaluation and applications.

### B.3 STAGE 3: Technical and Economic Evaluation of Options

#### B.3.1 Identify strategies and potential adaptation measures

The purpose of undertaking a climate vulnerability assessment is for the information generated from the exercise to inform the prioritisation of engineering and non-engineering adaptation options. These strategies and measures are meant to be exceptional and beyond the normal engineering solutions, but could become the norm in future if climate effects were to impact road infrastructure on a more frequent basis.

Based on an understanding of expected and current climate change impacts and vulnerabilities, the project team can identify strategies for a wide range of adaptation options.

Examples of adaptation strategies are provided in Section 4.1: *Adaptation strategies, Engineering Guidelines*.

Adaptation strategies aim to reduce the **impacts** of specific types of climate effects by identifying and prioritising adaptation options, which could include:

- Protecting existing assets or relocating assets away from vulnerable areas to preserve functionality
- Retrofitting vulnerable facilities
- Improving overall catchment/storm-water drainage
- Constructing new facilities
- Adopt an *Inadequate Funding* scenario approach and divert funds/efforts to facilities with greater priority.

In some cases, the best adaptation option(s) may be beyond the scope of an existing project or beyond the remit of the road authority. For example, realigning roads away from floodplains may be the most appropriate option in some situations but may be difficult to address at the project stage and almost impossible to address where the facility already exists. Others may include protecting the road infrastructure at the expense of accessibility during flooding (i.e. locate infrastructure at ground level instead of on embankments; the latter standing a greater risk of getting damaged during flooding). Similarly, watershed reforestation may be the most appropriate option in some situations. These should be taken up as part of an upstream planning process and can be flagged for such higher-level discussions.

The main objective when designing adaptation measures is to understand the geotechnical or structural problem and then develop techniques to resist the expected threats. In most cases, this would consist only of good engineering using well-understood and often conventional techniques.

#### B.3.2 Undertake stakeholder consultations

Identification of adaptation options will necessarily involve inputs from a number of stakeholders. Conducting roundtable consultations provides useful input for the process of identifying and appraising the whole range of adaptation options.

The sub-regional or local road authorities and communities are key stakeholders for a local-level climate risk and vulnerability assessment for roads. The involvement of communities in data collection is crucial. It is also crucial that they understand factors that render roads in their community vulnerable to climate. The benefit of increased community awareness to road authorities include receiving early warning about emerging structural damage on the roads, reduction of climate impacts through modification of land use practices and frequent clearing of debris and vegetation from culverts, bridges etc. Local government

representatives from the environmental, emergency and disaster management, agriculture and social development departments are important stakeholders in terms of provision and uptake of information ensuring that additional data gathered from local assessments is integrated into national spatial data repositories. They are also well positioned to implement change management recommendations on factors that are not intrinsic to the road infrastructure.

Full stakeholder consultations are recommended, and particularly when *Inadequate Funding Scenario* options are being considered, to look at consequences and mitigation strategies.

### B.3.3 'Inadequate Budget' strategy

Where an absence of adaptation policies, plans and programmes, and lack of funding create severe constraints to management of the road infrastructure then a strategy for an *Inadequate Funding* scenario should be developed. The term *Do nothing* is often wrongly 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; and that few actions can be undertaken. In a scenario of 'inadequate budget', proactive management strategies should still be developed to minimise disruption to rural access and socio-economic development.

Where relevant policies are absent or restricted then these should be developed or augmented to cover adaptation in its broadest sense and account for the '*Inadequate Budget*' scenario specifically.

The strategy will be directed at those areas or regions where there is evidence of adverse effects and where the vulnerability assessment has identified where the greatest risks are to assets, businesses and communities. The strategy should implement the following types of components to allow maximum active management of the network and to help to communities and local economies:

- Communication centre
- Agreed emergency plans with police, emergency services and military (the latter as a last resort)
- Preferred serviceability and accessibility criteria: This is the baseline against which all options can be gauged
- Key focal points requiring normal and emergency access
- An Early Warning Centre
- An emergency response Centre/Unit
- Vulnerable communities: collaboration needed within their structures to help maintain access
- Isolated Communities: contingency plans to be developed at a readiness state for implementation
- Key A to B routes with active diversions: to be deployed as part of a communication campaign; temporary diversions to be developed and managed
- Routes closed for short/long periods and permanently: contingency plans to be developed.

The strategy will be a balance between active and reactive management involving all stakeholders and communities. It requires a **management plan, communication plan and an implementation plan** with associated actions and responsibilities. These plans will then form the basis of a **cooperative communication and action campaign**. Modern smartphones permit almost immediate and detailed photographic indication of any problems following climatic impacts to be distributed from almost anywhere to those involved in implementing a rapid-response intervention.

**Recommended Actions** necessary to maintain a safe and serviceable network would include:

- Developing a proactive strategy and programmes to identify where options can be applied in a strategic way
- develop contingency plans;
- ensure delineation of alternative routes;
- establish temporary measures;
- address implications and consequences of *doing nothing* and have mitigation plans in place.

Full details and guidance are presented in Section 2.4: *Drivers for change, Change Management Guidelines*.

#### B.3.4 Socio-economic analysis of 'do something' and 'do nothing'

The goal of the economic analysis of adaptation options is to provide decision makers with information on expected costs and benefits of each technically feasible option identified and to rank these options according to the net total benefit (measured in present value terms) that each delivers. The options should then be compared with an equivalent '*do nothing*' scenario in order to fully appreciate the implications. Once these two scenarios are defined, the benefit of the adaptation option is assessed as the difference in the quantified and monetarised impacts with and without the options in place.

When implementing a '*do nothing*' strategy several sub-scenarios should be developed and tested to determine which actions reduce the cost and benefits least.

Given the significant uncertainty associated with the predicted impacts of climate change, conducting a cost-benefit analysis of adaptation options requires paying particular attention to the treatment of risk and uncertainty.

Amongst others, at least the following should be considered (ADB, 2011):

- Some adaptation options may also deliver benefits additional (co-benefits) to the climate-proofing benefits (e.g. the reforestation of a hillside in order to protect the road from landslides may also deliver fruit crops). These positive additional benefits need to be considered and may affect the ranking of the adaptation options based on a net present value criterion.
- While all adaptation options shall aim to climate proof the transport infrastructure, some adaptation options may do so at the expense of other sectors of the economy. For example, a floodwater diversion option may keep the transport infrastructure functional but increase flooding in another area. These impacts, whether intentional or not, need to be accounted for.
- Vulnerability may change over the lifetime of the project. Benefits of adaptation may be considerably different if based purely on an assumption of existing population or land-use, ignoring that future population or land-use may change. These changes in vulnerability need to be explicitly accounted for in the cost-benefit analysis.

Accounting for risk and uncertainty is particularly acute in the context of climate change. ADB (2011) recommends the following two approaches:

##### **Approach 1: Sensitivity analysis**

For conducting a cost-benefit analysis of an adaptation option, this simple type of analysis involves changing the value of one or more variables at a time and re-computing the option's net present value for each change. This exercise may be repeated as many times as necessary. In sensitivity testing, switching values are often computed, where a switching value is the value of a specific variable that makes the net present value switch from positive to negative, or conversely.

The purpose of such sensitivity testing is to raise the level of confidence when recommending the adoption or rejection of an adaptation option.

A key advantage of sensitivity testing is that it is extremely easy to conduct but has a number of severe limitations, including the following:

- Testing is highly subjective in that there is often no specific reason justifying the direction (smaller or larger) or the extent by which the value of a specific variable may be assumed to change.
- Testing does not take into account the probability that the value of any specific variable may differ from the value originally estimated. While sensitivity analysis allows computing a range of net

present values within which the actual net present value of the adaptation option may fall, it does not allow computing the expected net present value of the adaptation option.

## Approach 2: Probabilistic (or risk) analysis

Conducting a “probabilistic cost-benefit analysis” involves attaching a probability distribution for the possible value of any given specific cost or benefit component of the project instead of attaching a single deterministic value. Such probability distributions may be constructed using historical data.

Probabilistic (or risk) analysis allows selecting multiple variables that can all be varied simultaneously according to the specific probability distribution attached to each variable. This process, known as a Monte Carlo simulation analysis, involves randomly generating a specific value for each individual variable (cost component or benefit component) according to the specific probability distribution attached to each variable. For any given draw of specific values, the net present value of the adaptation option is calculated. This process, by means of computer, is then repeated many thousands of times.

The outcome of the analysis is a probability distribution of net present values. This probability distribution allows the computation of an “expected” net present value of the option, instead of solely a given net present value or a range of net present values. The same probability distribution also allows computing the probability that the net present value of the adaptation option will be negative.

Conducting probabilistic (or risk) analysis can be demanding if performed manually. However, packaged software allows Monte Carlo simulation analyses to be completed relatively simply.

From an economic point of view, not climate proofing a transport infrastructure may be the best course of action in certain circumstances. The outcome of the analysis of options, summarized as the net present value (NPV) of these options, will guide the nature of the recommendations. The *decision rule* guiding the selection of adaptations is similar to the decision rule for any investment project. If only one technically feasible adaptation option exists, then the *decision rule* is as follows:

- *If expected NPV > 0: Recommend implementing the adaptation option based on the outcome of the economic analysis.*
- *If expected NPV < 0: Recommend rejecting the adaptation option (do nothing) based on the outcome of the economic analysis*

If more than one technically feasible adaptation option exists, then the *decision rule* is to select the option with the largest expected NPV. If all adaptation options yield a negative expected NPV, then the best option is to do nothing

### B.3.5 Prioritise and select adaptation measures

The adaptation assessment results in a prioritised list of adaptation options for implementation, which are selected from among several possibilities or scenarios. Their prioritisation can be based on an assessment of their technical feasibility, their benefits and costs, their social acceptability, and the opportunities they may offer for synergies with national priorities. While the use and outcome of a cost-benefit analysis is often given more weight in the prioritisation process, it is important to recognise that other factors and criteria may also influence decision making.

The expertise required is multidisciplinary and as such is one of the more challenging aspects of adaptation planning. Roundtable discussions involving different stakeholders can work well and can include, for example, the project engineers, environmental specialists, social safeguards experts, nongovernment organisations, implementing entities, and national climate change representatives.

Where budgets are restricted, options will revolve around maintenance and emergency measures. Where budgets are absent, measures will be around community involvement and self-help.

Whichever climate adaptation measures are implemented, they are almost inevitably going to increase the cost of the provision of the majority of new roads or involve costs for the retro-fitting of such measures to existing infrastructure.

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 per cent of the total cost of providing that infrastructure. However, this climate resilience may decrease costs over a longer period by preventing damage to, and interruptions of the infrastructure and 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 prioritisation of needs. The process of prioritisation will need significant input from both road authorities and communities where different needs and importances may prevail and typically would require decisions of a strategic nature as discussed in Section A.4.2.2.

Generally, safety (loss of life) considerations will take precedence over the others. However, other than landslides, the safety implications of road failures are generally minimal. It should be borne in mind that it is still more important to ensure that the primary and secondary road networks are maintained in good condition before concentrating on the tertiary or low-volume access road network.

For more information, see Section 4.2: *Methodology, Engineering Guidelines.*

Based on an understanding of expected and current climate change impacts and vulnerabilities, a wide range of adaptation options can be identified. Once all adaptation options have been identified consultations should take place, followed by economic analysis and prioritisation of options.

## B.4 STAGE 4: Project Design and Implementation

Current National design guides are probably sufficient if implemented properly and with *adequate drainage* facilities for extreme events for critical infrastructure. The application of designs, however, needs a thorough understanding of the effects and impacts of climate issues on the roads and structures from both inside and outside its boundaries. An overriding problem affecting resilience is a *lack of appropriate and timely maintenance*.

### B.4.1 Develop implementation plans

The types of actions that can be taken to reduce vulnerability include avoiding, withstanding, and/or taking advantage of climate variability and impacts. Avoiding areas projected to have a higher risk of potentially significant climate impacts is an important factor in planning decisions but is often limited by other constraints (e.g. economic, environmental or social). 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 to increase bridge elevations beyond what historic data might suggest.

Secondly, the result of adaptive action either decreases a system's vulnerability to changed conditions or increases its resilience to negative impacts. For example, increasing temperatures could cause bituminous 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 will survive expected higher temperatures better.

With respect to resilience, operational improvements could be made to enhance detour routes around flood-prone areas. Another example of resiliency is well-designed emergency response plans, which can increase resilience by quickly providing information and travel alternatives when roads are closed and by facilitating rapid restoration of damaged structures. This will often involve institutional changes that allow rapid procurement processes and reserves (stocks) of necessary resources and plant. By increasing system resilience, even though a particular facility might be disrupted, the road network as whole still functions.

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.

- *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* - can be used to address rivers in spate, rising sea levels and storm surges. These may include drifts, dykes, seawalls, rocky aprons and breakwater systems.
- *Maintenance* – It is essential that all aspects of maintenance related to roads, drains, structures and vegetation control are diligently and timeously addressed. Most problems will be precluded by good maintenance.

**Recommended actions** for developing implementation plan:

- Reduce vulnerability by avoiding, reducing or taking advantage of impacts
- Take steps to ensure that the road infrastructure can withstand the projected changes
- Enhance detour and emergency response plans
- Follow primary engineering options set out above

**B.4.1.1 Insufficient funds scenario**

Often there is not enough budget to deal with all affected areas, roads and structures, or that the consequences of climate change are too severe to justify comprehensive physical adaptation. In these circumstances, a planned programme of dialogue with affected communities, well dispersed information and contingency programmes are necessary to minimise the adverse effects of these decisions.

In these circumstances, a continuous programme of monitoring and evaluation is needed in those areas where no physical interventions take place so that all unexpected circumstances can be dealt with, including emergency response.

This option is covered in more detail in Sections A.5.2: *Inadequate Budget Scenario* and in Section B.3.3: *'Inadequate budget' strategy*, **Climate Adaptation Handbook**

**B.4.1.2 Summary of Adaptation Methodology**

Appropriate and economic methodologies for risk and vulnerability assessments, prioritisation of adaptation interventions, and optimisation of asset resilience in the context of rural access low volume roads should be developed and reported. In addition, evidence of economic and social benefit links to rural communities arising from more resilient rural access are needed to support wider policy adoption across Africa. Assessment concentrates on future road scenarios for which detailed climate projections are developed.

The objectives are achieved through the following:

- i. Conceptual climate vulnerability and adaptation strategies
- ii. A methodology for mitigation and adaptation
- iii. Provision of options to create resilience
- iv. Provision of guidance for building adaptation strategies into roads policy, planning and standards
- v. Careful management of a *'do nothing' scenario*

The following activities should be conducted/ developed:

- Produce summary of climatic classifications currently used in road engineering;
- An inventory of all road elements that should be considered when addressing climate change effects;
- Prioritisation needs and options for adaptation strategies, including engineering and non-engineering options;
- Identify the potential hazards relating to the different expected climate stressors for all relevant facilities.
- Critical importance of incorporating adequate drainage, with timely and good maintenance practices.

Typical adaptation strategies include:

- Upgrade earth roads to at least engineered earth roads or gravel road standards;
- Improve material selection, construction practices, compaction and maintenance practices;
- Use innovative compaction techniques and water reducing technologies;
- On paved roads, use appropriate designs and surfacing including good drainage and maintenance;
- Apply the correct remedial procedures for problematic subgrades;
- Improve culvert and bridge designs and maintain properly;
- Improve maintenance procedures and training, consider community maintenance programmes;
- Upgrade gravel roads to paved standard where applicable;
- Stabilise slopes, including the application of vegetation, bio-engineering techniques;
- Use appropriate bituminous binders for surfaced roads (e.g. higher viscosity yet ageing-resistant binders for high road surface temperature environments);
- Enhance concrete mix designs and reinforcing;
- Apply precautionary measures against sand accumulation due to increased windiness;
- Use soaked subgrade designs for increased storm surges;
- Increase road level to a minimum of 0.5m-0.65m above normal groundwater level where possible and appropriate;
- Protect weaker subgrades with thicker pavements, and
- Make use of sub-surface drainage systems, where appropriate.

Ideally, some of the above measures should be embedded in norms and standards so as to ensure that they are applied routinely.

#### **B.4.2 Design parameters and optimisation**

During the design of new projects, it is essential that as many appropriate adaptations to improve the resilience of the project components to climatic effects are identified and incorporated in the design as economically possible. The importance of these adaptations will depend on the nature of the project components. For example, an unpaved road will always be susceptible, to varying degrees, to the vagaries of climatic influences and should be designed with a relatively short-term vision, as periodic maintenance is frequent and can overcome most climate-related problems. Bridges, on the other hand, even associated with relatively minor roads, are designed to provide a much longer service and should incorporate as many adaptations as necessary to ensure their long-term serviceability. It is difficult and expensive to retro-fit prematurely failed bridge components or reconstruct bridges that have failed. Similarly, the bituminous surfacing of paved road structures are rejuvenated or overlaid regularly and can be “repaired” during these interventions. The pavement structures and support layers must last the design-life of the pavement and should thus incorporate as many adaptation measures as are necessary, as these are costly to repair later during the pavement operation.

It is more difficult to implement adaptation measures on existing roads. Although the potential problems and vulnerable areas are often identified during current inclement weather conditions, there is seldom funding available for the rectification of all (or often even some) such problems and the effective implementation of resilience adaptations. However, it is important that as much resilience engineering as possible is implemented in the highest priority areas and that during any upgrading, reconstruction or rehabilitation, the remaining measures are implemented.

#### B.4.2.1 Design to improve resilience

Whilst engineering solutions to make a climate resilient road are similar to those within existing National design manuals, knowledge of appropriate hydrology (storm return periods, groundwater and water flows) is generally poor. There are many adaptations or specific design decisions that can increase the resilience of roads to climate change.

A full description of these, along with design considerations, is set out in Section 5.3: *Roads* and in Section 5.4: *Subgrade soils, Engineering Guidelines*.

Adaptations required for different road attributes explained within the *Engineering Guidelines*, along with respective *design considerations*, are classified as follows:

- **Roads**
  - Unpaved roads
    - Un-engineered earth roads
    - Engineered earth roads
    - Gravel roads
  - Paved Roads
    - Thin bituminous surfacing
    - Asphalt surfacing
    - Concrete surfacing
    - Other non-bituminous surfacing
  - Earthworks
    - Cuttings
    - Embankments
    - Erosion
- **Subgrade soils**
  - Expansive Clays
  - Dispersive/erodible/slaking materials
  - Saline soils
  - Soft clays
  - Wet areas/high water tables
  - Collapsible soils

#### B.4.2.2 Drainage

Water falling directly onto the road carriageway, shoulders and embankment slopes and which ultimately flows into the side drains requires particularly good control. The primary objective is to make sure that this water does not get into the pavement structure or subgrade, whether it is an unpaved or a paved road. Other requirements are that the water does not accumulate on the surface of unpaved roads (leading to softening and deformation), that the water flows off paved roads so as to minimise the risk of skidding/aquaplaning, movement of the water off the surface does not lead to erosion of the road surface (paved or unpaved) or the shoulders and that the water actually gets into the side drains where it can be effectively removed from the road environment into mitre drains or culverts.

How to deal with water from within and from outside the road reserve is addressed in Sections 5.5 and 5.6: *Drainage, Engineering Guidelines*. Design considerations for bridges and culverts are provided.

#### B.4.3 Construction, maintenance and supervision

During the predicted extended **dry periods** in some areas (also being **hotter**), the availability of construction water may be limited for longer periods and longer haulage distances may be necessary. The cost of the water is also expected to rise as construction competes with other uses for its limited availability and the

quality of available construction water is expected to deteriorate. Simultaneously, the water applied to the layers during these periods for compaction will evaporate much quicker and greater quantities of water will be required.

During extended **wet periods** site access can become difficult or even impossible and compliance with specifications may not be practicable. Many countries cease both construction and maintenance during rainy seasons.

The main construction problems affecting the resilience of roads to extreme climatic conditions is the lack of compaction. Poor compaction within the formation/embankment materials, the shoulder materials or even the structural layers is usually manifested as rutting, undulations or excessive vertical deformation in affected areas. These conditions need to be identified, as the permeability of the materials in these areas will be significantly higher than well-compacted materials and the potential for premature failures due to water ingress is increased.

Maintenance techniques are unlikely to change significantly for adaptation needs: however, the frequency and types of maintenance will need to be increased to address changes in climate, especially extreme weather events. Maintenance is an essential part of preserving any road and should be judiciously carried out. As climatic conditions change, the need for more, and good quality, maintenance is going to become increasingly critical. During the assessments, issues such as the retention of shape of shoulders, cutting and clearing of vegetation, removal of termite nests and bushes on embankments (that are likely to induce turbulent flow of water flowing over the embankment), cleaning and shaping of side-and mitre drains and ensuring that culverts and drains are not blocked must be noted.

Further guidance is provided in Section 5.8: **Maintenance, Engineering Guidelines.**

The importance of minimising the risk of wind-induced wild-fires that burn the vegetation and soil cover, allowing exposure of the soil to intense storms (more of these are expected) and consequent erosion cannot be overemphasised. This is particularly relevant on embankment and cut slopes, around drainage structures and in areas where the soils are inherently susceptible to erosion. Increased damage to wooden structures and road furniture can also be expected if vegetation growth is not controlled.

It is also essential that potholes are repaired regularly with a well-compacted, high-quality impermeable cold-mix asphalt and all cracks in the road surface are regularly sealed.

## **B.5 STAGE 5: Monitoring and Evaluation**

### **B.5.1 Develop monitoring and evaluation plan**

This is one of the most important aspects of climate adaptation. It is essential that the effectiveness and performance of any adaptation measures are fully monitored and evaluated. It is only in this way that shortcomings, problems and inefficiencies can be identified and modifications or alternative solutions can be implemented with the advantage of hindsight for future implementation during design. This is easier done for roads and structures with short design lives but cannot be effectively done for larger structures with design lives of 50 or 100 years.

There is little experience worldwide in understanding how effective the different options to reduce vulnerability to climate change actually are, making monitoring and evaluation all the more important to develop improved knowledge. There are a number of challenges in doing so, including the long-term nature of actual climate change, the need to acquire appropriate baseline data and metrics for measuring vulnerability and isolating vulnerability to climate change from other sources of pressure.

The development of outcome level and output level indicators to assess the impacts of adaptation investments is ongoing. ADB (2011) identifies three levels of results monitoring: impacts, outcomes, and outputs.

Various issues can be monitored to identify the effectiveness of the adaptations as follows`:

- Reduction in delays: number of days that the roads within the network are impassable or journey times are increased
- Cost implications: changes in costs of maintaining and repairing the road network after climatic effects
- Social implications: improved accessibility, mobility and economic development, either measured, observed or perceived by the local communities.

Table 3 provides some examples of indicators at each level. Given the challenges related to measuring for impact, which may occur beyond the project life, output level indicators may be the most robust.

**Table 3 Typical indicators of results monitoring (after: ADB, 2011)**

Indicator Type	Indicator
<b>Impacts (long-term effect)</b>	<ul style="list-style-type: none"> <li>▪ Increased robustness of infrastructure design and long-term investment development</li> <li>▪ Increased resilience of vulnerable natural and managed systems, such as flood management</li> </ul>
<b>Outcomes (process indicators)</b>	<ul style="list-style-type: none"> <li>▪ Percent reduction in road closures due to structural failure, landslides or flooding</li> <li>▪ Percent reduction in flooding where drainage capacity has been increased</li> <li>▪ Improved decision making and sector planning based on climate change considerations</li> <li>▪ Improved rural access</li> </ul>
<b>Outputs</b>	<ul style="list-style-type: none"> <li>▪ Transport sector planning and documents include adaptation strategies</li> <li>▪ Design and specification documents have resilience measures built in</li> <li>▪ Maintenance programmes routinely cover preventative measures</li> <li>▪ Length of road constructed to withstand climate change impacts</li> <li>▪ Area of environmental protection measures</li> </ul>

### B.5.2 Report and share implementation experiences

An adequate adaptation strategy is likely to be composed of a number of activities including *engineering measures*, such as incorporating design changes, and *non-engineering measures*, such as ecosystem resilience measures and early warning systems for disasters. Lessons from adaptation measures undertaken at a project level should inform policy makers about appropriate approaches at the sector and/or national levels.

There are several recommended ways of reporting and sharing experiences, as follows:

- Briefing documents, for circulation and distribution
- Programme/Project reports
- Monitoring and evaluation reports, fact sheets
- Feedback reports to stakeholders, both at policy level and at donor levels
- Published case studies and demonstrations
- Lectures, conferences and discussion forums
- Seminars, workshop and training events
- Capacity building programmes, including train-the-trainer programmes.

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