AfCAP
Africa Community Access Partnership

UKaid
from the British people

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

Change Management Guidelines

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

AfCAP Project GEN2014C

November 2018

CSIR
our future through science

PGC

ST HELENS

Head, M., Verhaeghe B., Maritz, J., Council for Scientific and Industrial Research (CSIR) (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa, Change Management Guideline, GEN2014C. London: ReCAP for DFID.

For further information, please contact: Benoît Verhaeghe, BVerhaeg@csir.co.za

ReCAP Project Management Unit
Cardno Emerging Market (UK) Ltd
Level 5, Clarendon Business Centre
42 Upper Berkeley Street, Marylebone
London W1H 5PW United Kingdom

Cover Photo: Benoît Verhaeghe

Quality assurance and review table

Version	Author(s)	Reviewer(s)	Date
1	M Head, B Verhaeghe	L Sampson, Dr J Cook	August 2017
2	M Head, B Verhaeghe , J. Maritz		November 2018

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

Reference No:	GEN2014C	Location	Sub-Saharan Africa
Source of Proposal	DFID/ReCAP	Procurement Method	Tender
Theme	Sustainability of access	Sub-Theme	Climate resilience
Lead Implementation Organisation	CSIR	Partner Organisation	Paige-Green Consulting St Helens Consulting
Start Date	April 2017	End Date	December 2018
Report Due Date	November 2018	Date Received	November 2018

Contents

Key words v
Glossary (within the context of this project) vi
Acronyms, Units and Currencies ix

Summary 1

1 Background and Context 2
1.1 Aims and objectives 2
1.2 Scope 2
1.3 Introduction to the Climate Adaptation Handbook 3
1.3.1 Application 3
1.3.2 Content of the Handbook 4
1.3.3 Using this guide 6

2 Situational Review and Adaptation Management 7
2.1 Vulnerability and projected population 7
2.2 Projected Climate Change over Africa 9
2.3 Main effects of climate change 10
2.3.1 Failure to act 11
2.3.2 Poor maintenance 11
2.3.3 Inadequate budgets 11
2.4 Drivers for change 12
2.4.1 Policy and plans 12
2.4.2 Policy options for climate adaptation 13
2.4.3 Translating policies into strategies and plans 15
2.4.4 Adaptation management in cases of poor or inadequate budget scenarios (also referred to as the Do Nothing or Minimal approach) 18

3 Change Management 20
3.1 Integrated approach 20
3.1.1 Identify and mobilise stakeholder and expertise involvement. 20
3.1.2 Improved network and programme management to anticipate and mitigate impacts 21
3.1.3 Improved asset management resilience 22
3.1.4 Maintenance planning and early warning 23
3.1.5 Actions following a disaster event 24
3.1.6 Environmental management 25
3.1.7 Hydrological management 27
3.1.8 Augmenting standards and design guides 27
3.1.9 Road safety 29
3.1.10 Research 30
3.2 Managing the adaptation process 30
3.2.1 Adaptation options in the roads sector 30
3.2.2 Prioritisation of adaptation needs 31
3.3 Embedment 36
3.4 Capacity building 36

4 Approach and Delivery 38
4.1 Funding and climate vulnerability screening 38
4.2 New infrastructure and structures 39

4.3 Rehabilitation and retrofitting 39
4.4 Maintenance 40
4.5 Do-minimal approach 40
4.6 Management of delivery 41

5 Effective Data Management....42
5.1 Data and Asset Management 42
5.2 Slope management system 46
5.3 Collect and analyse data and information 47
5.3.1 Determine classifications and methods of assessment 48
5.3.2 Method of assessment 48
5.3.3 Role of assessors 49

6 Climate Risk Screening....50
6.1 Needs determination 50
6.2 Identify and mobilise stakeholder/partner involvement 50
6.3 Setting of policy, objectives and scope at network level 51

7 References 53

Tables and Figures

Table 1: Contents and scope of the Adaptation Methodology 5
Table 2: Rural Population growth in AfCAP countries and partner countries 8
Table 3: Policy Options for Adapting the Transport Sector to Climate Change (BPC, 2010) 14
Table 4: Immediate Priorities following a disaster (based on Ferreira et al, 2010) 24
Table 5: Guidelines for Levels of Serviceability for mobility 33
Table 6: Guidelines for Levels of Serviceability for accessibility 33
Table 7: Recommended actions to integrate change in AM practices (NAMS, 2011) 44
Table 8: Recommended adaptation strategies and monitoring techniques for the asset management system components (Ebinger and Vandycke, 2015) .46

Figure 1: Applications covered in the Handbook 3
Figure 2: Strategic approach based on type of activity and adequacy of funding available 6
Figure 3: Rural population growth/decline for AfCAP countries and partner counties 1950 – 2050 (custom data acquired via UN ESA, 2018) 8
Figure 4: Example of projected changes in maximum temperature and extreme rainfall events 9
Figure 5: Examples of projected changes in rainfall and average value of the Keetch-Byram drought index 9
Figure 6: Generalised government structure with policy links 12
Figure 7: Processes to set, implement and update policies and strategies 15
Figure 8: Climate driver impacts resulting in need for adaptation strategies 16
Figure 9: Prioritisation of changes to design standards and proposed changes to management 28
Figure 10: Accessibility verses mobility for road type 33
Figure 11: Hierarchy of delivery systems for climate resilience 41
Figure 12: Assessment of assets for RAM for prioritisation and budgeting 42
Figure 13: Asset management process versus response timing (NAMS, 2011) 43
Figure 14: Example of a typical landslide susceptibility map for South Africa 47

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.

An independent Climate Adaptation Handbook has been developed that particularly addresses part (a) of this study focus in detail as well as paying attention to aspects relating to parts (b), (c) and (d). The Guideline presented in this document acts as a supporting document to the Handbook and is specifically aimed at providing change management guidelines relating to non-engineering adaptation options.

Key words

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

Glossary (within the context of this project)

Adaptation	Autonomous or policy-driven adjustments in practices, processes or structures to take account of changing conditions.
Adaptive Capacity	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].
Adaptation Needs	The circumstances requiring actions to ensure safety of populations and security of assets in response to climate impacts.
Adaptation Options	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.
Capacity Building	The ability of enhancing strengths and attributes of, and resources available to, an individual community, society, or organisation to response to change.
Change Management	A collective term for all approaches to preparing and supporting individuals, teams, and organisations in making organisational or institutional changes in order to equip them to address and resolve new or recurring challenges impacting on them and their stakeholders (e.g. impacts of climate variability and change on their operations)
Climate Change	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.
Climate Variability	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).
Disaster	Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency responses to satisfy critical human needs and that may require external support for recovery.
Early Warning Systems	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.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
Extreme Weather Events	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. *Impacts* are used here 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. The impacts of climate change on geomorphological 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).

Acronyms, Units and Currencies

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

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[1] (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.

The Handbook on Climate Adaptation[2] provides a methodology for carrying out a climate adaptation assessment for rural access to support socio-economic sustainability. It also 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
- Climate Threats and Vulnerability Assessment[3]
- Engineering Adaptation[4].

This Guideline is a supporting document that deals with change management related to climate change adaptation.

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

[2]Head, M; Verhaeghe, B; Paige-Green, P; le Roux, A; Makhanya, S and Arnold, K. (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Climate Adaptation Handbook,* GEN2014C. London: ReCAP for DFID.

[3]Le Roux, A; Makhanya, S; Arnold, K and 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.

[4]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 Background and Context

1.1 Aims and objectives

The overall project aim is to advance previous AfCAP research and deliver sustainable enhancement in the capacity of AfCAP partner countries to reduce current and future climate impacts on vulnerable rural infrastructure. The study covers threats and adaptation options for both existing and new infrastructure. 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*** of the project is to identify, characterise and demonstrate appropriate engineering and non-engineering adaptation procedures that may be implemented to strengthen the long-term resilience of rural access, based on a logical sequence of defining:

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

The second objective, which focusses on ***capacity building and knowledge exchange***, is to meaningfully engage with relevant road and transport Ministries, Departments and Agencies/Authorities in a knowledge dissemination and capacity building programme based on the outputs from research being conducted.

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

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

1.2 Scope

The Climate Adaptation regional programme aims 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 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 project is supported by demonstration studies that were conducted during the project to assess the appropriateness and practicality of the recommended approaches for climate adaptation. These studies were carried out in three countries, namely Ethiopia, Ghana and Mozambique. These countries represent and cover nearly the full range of agricultural systems found in Africa. Countries such as Mozambique are commonly subjected to extreme events such as floods and tropical cyclones. Both Mozambique and Ghana are on the receiving end of water flowing out of major international river basins. With most of their economic activity and population concentrated along the coast and in low-lying deltas.

1.3 Introduction to the Climate Adaptation Handbook

The Climate Adaptation Handbook is the overarching document that provides relevant information on climate adaptation procedures for rural road access, along with instructions on an appropriate methodology for addressing climate threats and asset vulnerability, 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 Ethiopia, Ghana and Mozambique, but equally applicable to any of the other Sub-Saharan African countries.

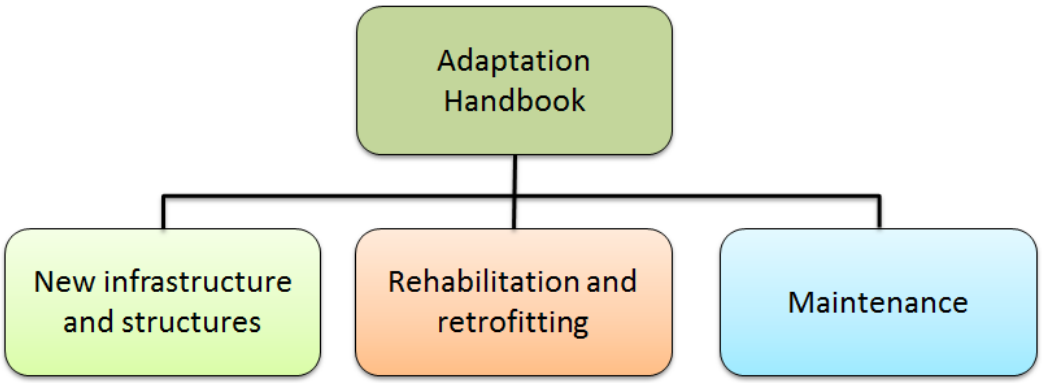
The Handbook illustrates the fundamental principles, processes and steps required for climate resilience. Details regarding actual adaptation measures are included in the accompanying Guideline documents covering *Change Management* (Non-engineering options)*, Climate Threats and Vulnerability Assessment*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

1.3.1 Application

Although the Handbook has been developed for *low volume road applications,* most of the principles that are contained within the Handbook may also apply to *high volume roads.* It is however important to note that the priorities and design parameters for low volume roads may differ to 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 take note of the following:

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

New Infrastructure and structures

Construction of new infrastructure is rare. 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 usually still low volume), together with improvement of existing or construction of new drainage structures.

Rehabilitation and retrofitting

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

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

Maintenance of existing infrastructure

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

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

1.3.2 Content of the Handbook

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

The Handbook also pays attention to management of measures that could be taken when budgets are inadequate or absent under a specific *Inadequate Budget* scenario.

This guideline document features the change management aspects in more detail. This guideline features the items listed in Part A of the Handbook as well as parts of the methodology (see items highlighted in green as shown below)

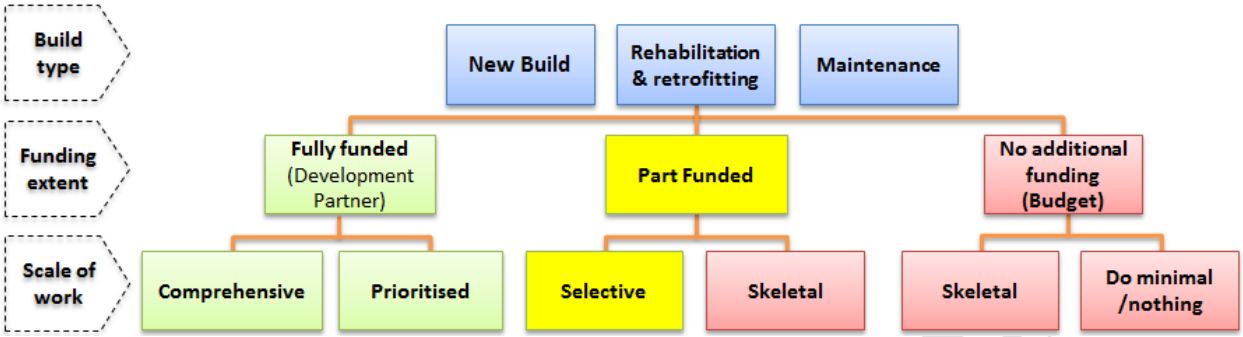
Table 1: Contents and scope of the Adaptation Methodology

Part A	**Situational review and adaptation management**
Covers:	Problem identification (including evidence) Identify probable causes Drivers of change (policy driven) Change management Approach and delivery Effective data management
Part B	**Methodology**
Stage 1	***Climate risk screening (national/regional)***
B.1.1	Needs determination
B.1.2	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.1.5	Data gathering and risk analysis
Stage 2	***Impact and vulnerability assessment (project level)***
B.2.1	Project-level climate risk screening
B.2.2	Climate impact assessment
B.2.3	Data gathering and vulnerability assessment
Stage 3	***Technical and economical evaluation of options***
B.3.1	Identify strategies and potential adaptation measures
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
Stage 4	***Project design and implementation***
B.4.1	Develop implementation plan (including 'Inadequate Budget' scenario)
B.4.2	Design parameters and optimisation
B.4.3	Construction supervision and documentation
Stage 5	***Monitoring and Evaluation***
B.5.1	Develop monitoring and evaluation plan
B.5.2	Report and share implementation experiences

Figure 2 illustrates the manner in which the strategic approach will vary based on the type of activity and adequacy of funding available. Development Partner funding (as shown in Green) will normally be comprehensive/prioritised whereas part-funded projects (shown in yellow) will require prioritisation that is highly selective and may, by necessity, be skeletal in the activities that can be funded. Feedback provided by AfCAP partner countries identified maintenance as being heavily underfunded or, in some cases, absent. In such cases the activities will be based on available resources (as shown in red). This strategic approach is further discussed in Section 2.1.3: Inadequate

Budgets; Section 2.2.4: Adaptation management in cases of poor or inadequate budget scenarios; Section 4.5: Do minimal; and Section 4.6: Management of Delivery.

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



Addressed in more detail in section 4.6

1.3.3 Using this guide

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

Section linked to the **Adaptation Handbook.**

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

Information Box

List of recommended actions are also placed in summary boxes which are marked orange (see below).

Recommended actions:

Some remarks are also made dealing specifically with a poor, inadequate budget situation (predominantly referred to as the 'Do minimal' or 'do nothing' scenario. See green marked boxes.

Remarks considering a poor, inadequate or absent budget scenario

2 Situational Review and Adaptation Management

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

2.1 Vulnerability and projected population

The African Development Bank (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, will be higher in Africa than in any other region in the world.

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

Many communities and countries are dependent on natural resources to sustain their livelihoods and as a result of their dependency, exposure and vulnerability have been particularly at risk to loss of life, livelihoods and economic activity when natural hazards do occur. The high social vulnerability and low adaptive capacity of these communities as well as their high exposure to natural hazards has resulted in the death of more than 600,000 people (95 per cent 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 (CRED, 2016).

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

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

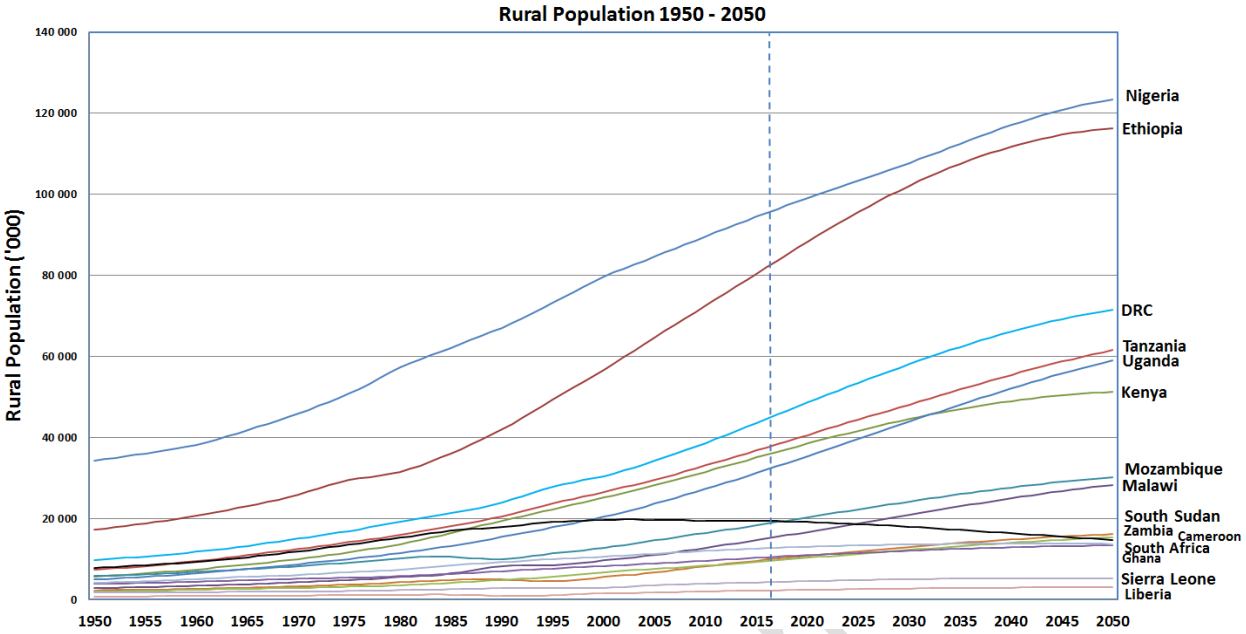


Table 2: Rural Population growth in AfCAP countries and partner countries

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

2.2 Projected Climate Change over Africa

Examples of projected climate change over Africa are displayed in Figures 4 and 5. Figure 4 provides an example of the projected changes across a range of downscalings for maximum temperature (left) and extreme rainfall events (right). Similarly, Figure 5 illustrates changes in rainfall (left) and the average value of the Keetch-Byram drought index (right), for the period 2080-2100 relative to 1961-1990 under a low mitigation scenario.

Figure 4: Example of projected changes in maximum temperature and extreme rainfall events

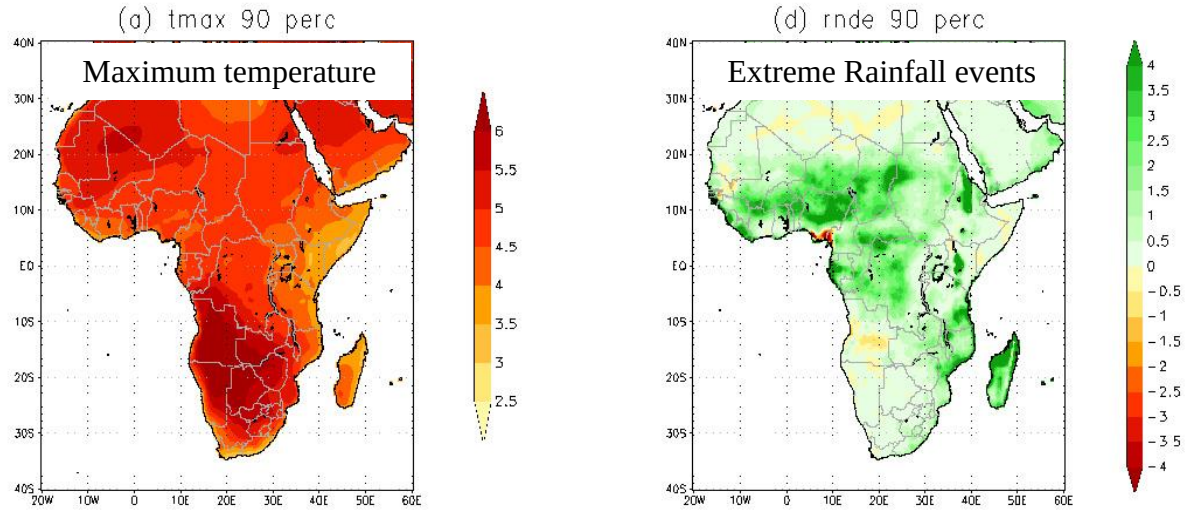
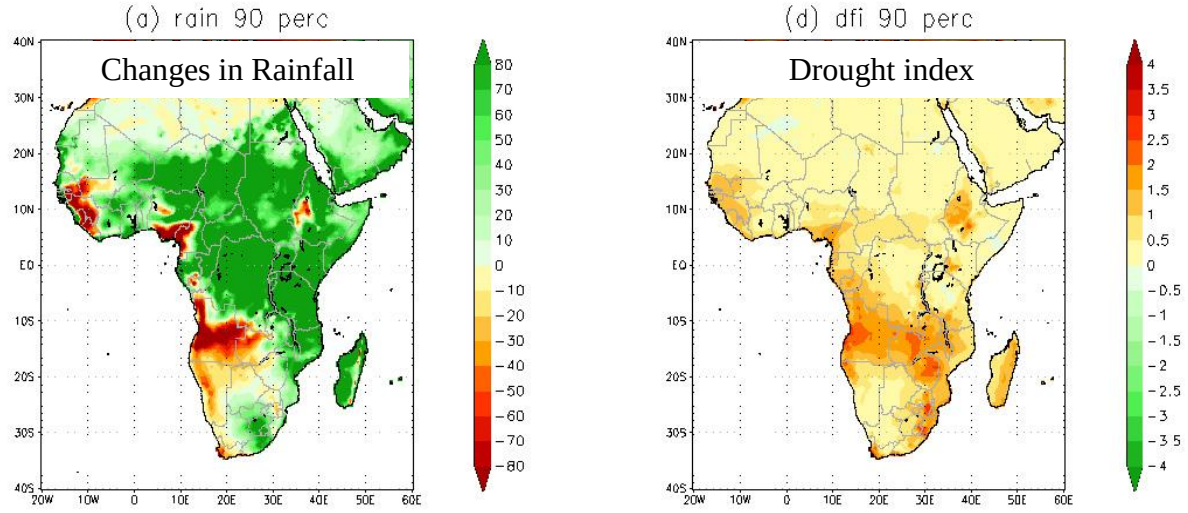


Figure 5: Examples of projected changes in rainfall and average value of the Keetch-Byram drought index



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

Sahel, with some climate models projecting wetter conditions and equally credible models projecting drier conditions under climate change (e.g. Christensen et al., 2007; Niang et al., 2014).

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

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

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

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

2.3 Main effects of climate change

The most commonly reported problem currently related to climate change is caused by flooding. This is due to more frequent and more intense extreme events resulting in damage or total destruction of roads and associated structures. Another common problem is land movement affecting natural slopes adjacent to roads as well as cuts and embankments which comprise part of the road development. These problems are generally exacerbated by a number of factors such as:

- Failure to take into account extreme conditions and signs indicating impending problems and to take appropriate action
- Failure to maintain the infrastructure adequately
- Failure to have funding available to implement timely preventative measures

The following briefly elaborates on each of these factors.

2.3.1 Failure to act

Not taking action to address the risks associated with extreme climate events stems from 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 inability to address the problem
- Insufficient funds: either through not appreciating the scale of the problem or inability to secure funding.

Many governments on the African continent 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 result in increased costs related to dealing with disruption, loss of access, rehabilitation and socio-economic development. Shocks from unexpected extreme climate events also severely undermine community and business resilience and harms the development gains made in such regions.

2.3.2 Poor maintenance

Historically, road asset maintenance has been sporadic and inadequate resulting in deteriorating assets. Records, management systems, supervision, monitoring and quality control have been weak or outdated. Problems have been exacerbated by some reluctance of Development Partners to set up maintenance funds within their new build or rehabilitation programmes. Consequently, significant maintenance backlogs are commonplace across the continent.

2.3.3 Inadequate budgets

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

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

Based on consultation held with national stakeholders and responses received on a questionnaire that was sent out, there is clear evidence that the lack of funds and inadequate budgets (to deal with the effects of climate change) are prevalent across AfCAP partner countries, resulting in substantially underfunded maintenance, capital works and associated programmes. In many countries, only routine maintenance is carried out unless Development Partner funding is available.

Managing access for road infrastructure for the rural population is particularly challenging in these circumstances, often referred to as a *No-Adapt* or *Do-nothing* 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 programmes, emergency planning and stakeholder collaboration. Specific guidance on this is set out in *Adaptation Management with Inadequate Budgets Scenario* in Section 2.2.4 and throughout Section 3 for these circumstances.

2.4 Drivers for change

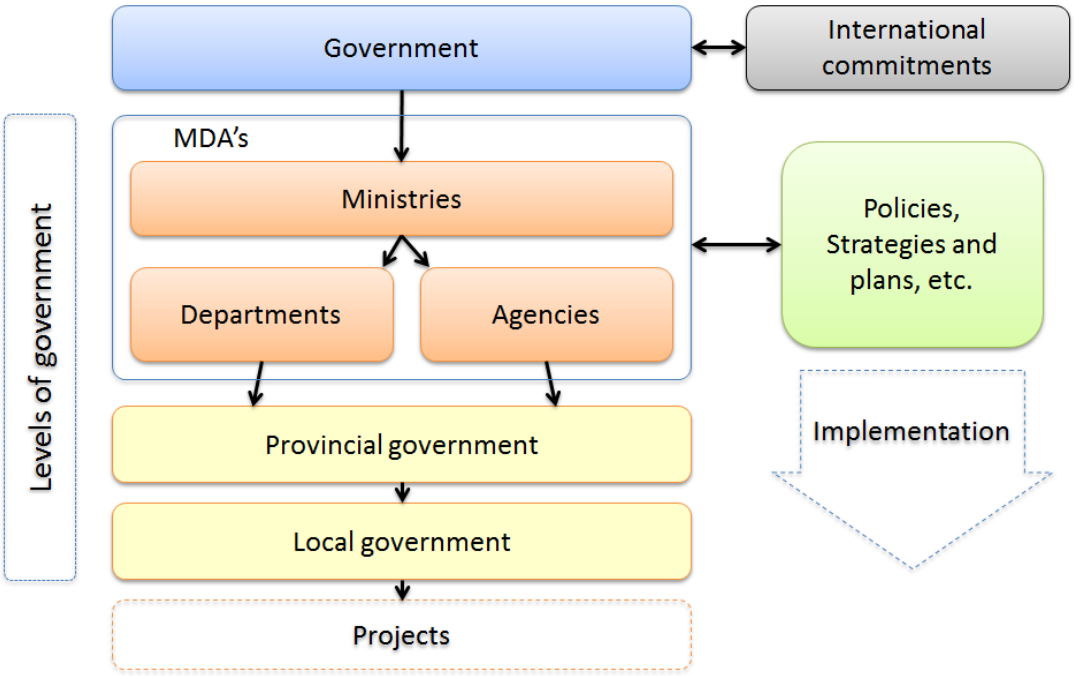
Effects from changing and more extreme climate events are becoming commonplace in many African countries. Although multisector policies on climate change are being addressed in many countries, policies and strategies specific to the roads and related infrastructure sector are often lacking. The modification of policies, strategies and plans are required to change how climate change is addressed.

It is essential that the necessary view and understanding are modified at the highest levels. These should incorporate climate change considerations into government goals and policies and could be general statements concerning adequate attention of potential issues, or targeted statements at specific types of vulnerabilities (e.g., sea-level rise).

2.4.1 Policy and plans

Government and MDA's (Ministries, Departments, agencies/authorities) policies on climate adaptation for Road and Transport are almost absent. Where present, roads are usually represented as a subset of all infrastructure, including energy and water supply, but it is more common for adaptation policies to be multi-sectoral, covering agriculture, energy, forestry, etc. Development Partners, particularly, the World Bank, are now recognising the importance of establishing specific policies and strategies for the road sector. Policy development is usually an integral part of strategic planning, programming, implementation and feedback. Policy sets the scope and content for strategic planning for programmes and plans which, when implemented will create more sustainable rural access. Monitoring and evaluation will provide evidence and experience that can be fed back to modify/improve policy.

Figure 6: Generalised government structure with policy links



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

Actions to accommodate or improve climate adaptation:

- Review Government Policy
- Review Environmental Policy
- Review 20, 10 and 5-year Development Plans
- Inspect strategies of Ministries, Departments, Agencies/Authorities
- Augment sectorial goals, objectives and strategies
- Foster cross-sectorial cooperation and multidisciplinary management
- Modify scope of national climate change committees
- Decide modifications and implementation programme to above

2.4.2 Policy options for climate adaptation

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

Due to poor coordination between sectors and limited capacity for mainstreaming, Climate Adaptation in planning and budgeting documents and the widespread recognition of adaptation as an important issue among public, private and civil society actors has not resulted in effective adaptation and mitigation activities. Instead, independent actions have been sporadic and ineffective, despite the inclusion of adaptation and mitigation policies and strategies in the environmental sections of central and district-level government.

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

- Extent to which the policy, strategy, regulation, or plan under consideration could be vulnerable to risks arising from climate variability and change.
- Extent to which climate change risks have been taken into consideration in the course of programme formulation.
- 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.

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

Recommended policy option actions for adapting the transport sector to climate change, developed by the Bipartisan Policy Centre (BPC, 2010), are shown in Table 3. It describes the research/policy

objectives and sets out appropriate policy responses. It covers the full spectrum of planning, asset management, institutional changes, standards/regulations and performance measures.

Table 3: Policy Options for Adapting the Transport Sector to Climate Change (BPC, 2010)

Research/Policy Overview	Policy Description
Develop appropriate model outputs	Integrate climate data and projections, and more information about the likelihood and extent of extreme events, into transport planning.
Inventory assets	Inventory of transport infrastructure and locations that are vulnerable to climate impacts.
Identify secondary impacts	Conduct research on demographic responses to climate change and land use interactions, and how these responses impact the transport sector.
Support decision making	Provide modelling and adaptation planning tools to local governments to help identify vulnerabilities.
Coordination and collaboration	Facilitate and support cross-disciplinary coordination and collaboration among the public sector, private sector, and local stakeholders to assess impacts, vulnerabilities, and adaptation options.
Emergency preparedness planning	Develop climate change strategies to integrate emergency response into transport infrastructure design and operations.
Expand planning timeframes	Transport agencies need to incorporate the effects of longer-term climate change into their planning processes.
Refine risk analysis tools	Planners/engineers require support to develop and use probabilistic techniques in risk analysis tools to address uncertainties that are inherent in projections of climate phenomena.
Land use	Work with appropriate agencies to influence land use decisions and avoid inappropriate development in high-risk areas.
Develop risk assessment and adaptive management approach	Adopt an iterative risk management approach to provide transport decision makers a more robust picture of the risks to various components of the transport network.
Develop new design standards	Develop new design standards and codes to incorporate projected changes in climate conditions.
Update regulations	Require climate change adaptation screening in environmental impact assessments.
Institutional changes	Make institutional changes to facilitate integration of climate change impacts into the decision-making process for transportation planning and investment.
Assessment of costs and benefits	Provide guidance to identify opportunities for adaptation and to assess cost estimates and benefits for adaptation initiatives and programs.
Performance measures	Develop performance measures to inform prioritisation and decision making on adaptation approaches and projects.

Where relevant policies are absent or restricted then these should be developed or augmented to cover adaptation in its broadest sense. Where an absence of adaptation policies, plans and programmes, and lack of funding, creates severe constraints to management of the road infrastructure then a strategy for an *Inadequate Funding* scenario should be developed. The term 'Do Nothing' is normally used to signify little or no designated budgets or funds to deal with adaptation relating to vulnerability threats, existing damage backlog or maintenance issues relating to road assets and so few actions are taken. In such a scenario a proactive management strategy should be developed to minimise disruption to rural access and to socio-economic development.

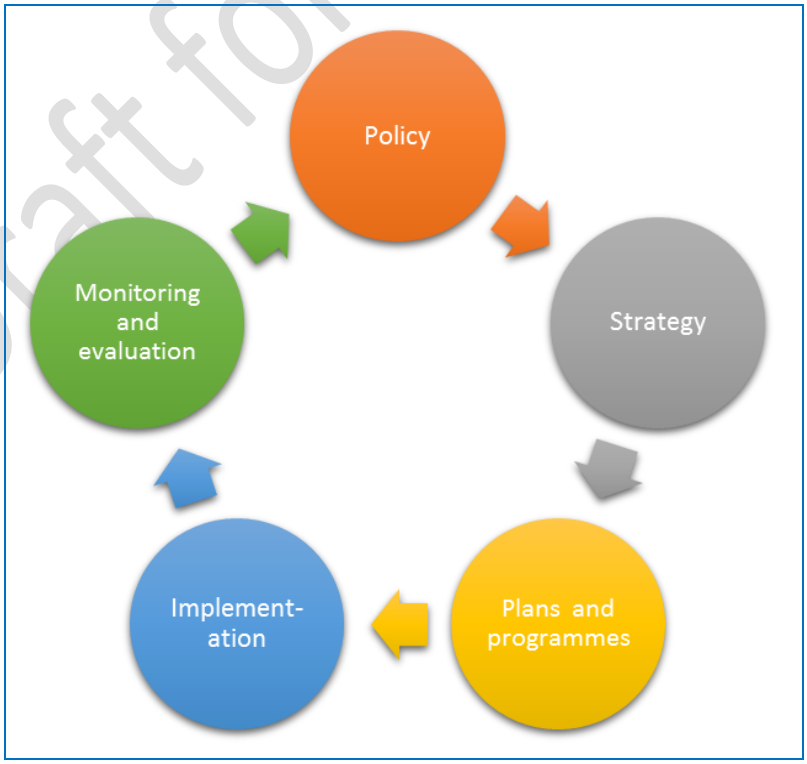
2.4.3 Translating policies into strategies and plans

At a strategic level, it is preferable to develop a national climate threat, vulnerability and adaptation strategy 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.

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

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

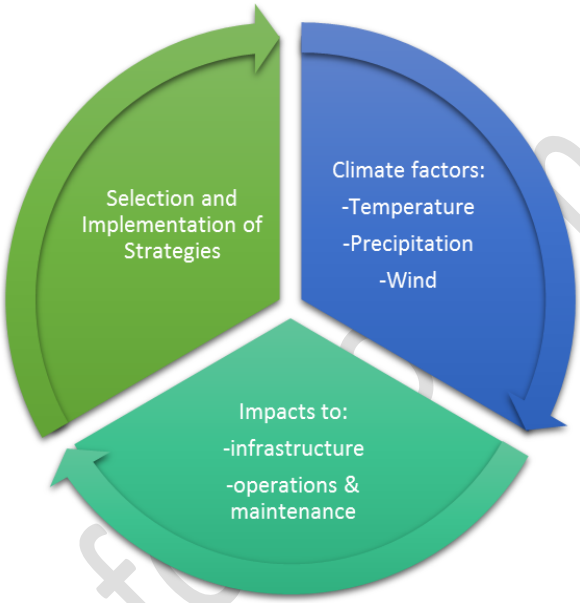
Figure 7: Processes to set, implement and update policies and strategies



Climatic factors have direct impacts on the condition of infrastructure as well as for its operations and maintenance. Once the significance of these implications is assessed, adaptation strategies can be developed to respond to these impacts, see Figure 8. These adaptation responses will, in turn, affect the condition and resilience of the infrastructure, as well as the operations and maintenance requirements.

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

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



Decisions pertaining to priority areas, alignment, land zoning, spatial planning, technology, and implementation plans are also generally made at policy and sector planning levels (ADB, 2011). Many of the examples of international adaptation strategies rely on the participation of multiple partners, such as ministries of infrastructure and ministries of environment, which is more readily established if set at the policy level.

Information Box 1

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

Four priority areas where action by national governments could support infrastructure resilience are (OECD, 2009):

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

Recommended actions:

- Build awareness and capacity to facilitate relevant partnerships.
- Incorporate adaptation considerations into, for example, transport master plans. This will further secure the likelihood of meeting transport-related objectives and may also identify new priorities.
- Align spatial planning policies, national and international technical standards, and economic policies and 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.

Information Box 2:

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

Implementation of an Adaptation Strategy will require sufficient trained resources to implement action plans and programmes.

Recommended actions:

- assign sufficient resources to adaptation activities, to provide the capability to implement a phased and consistent approach to addressing climate change risks;
- 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;
- initiate a 'quick-wins' programme leading to the early implementation of adaptation actions where these are straightforward, low cost and their benefits are clear.

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

Similar processes should be applied for adaptation policy for vulnerable communities and where there are inadequate budgets for specified areas or activities. 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 have the following components as a minimum to allow maximum active management of the network and help to communities and markets:

- **Preferred serviceability and accessibility criteria:** This is the baseline against which all options can be gauged. It conforms with agreed strategies and management targets relating to serviceability and accessibility.
- **Key focal points requiring normal and emergency access:** these relate typically to medical, educational, welfare, key supplies, water supply, power supply type facilities. Ideally they should be identified through a GIS system and incorporated into an asset management system.
- **Early warning:** linking local monitoring with real time regional meteorological information to provide an early warning management system that can be translated into a series of actions by coordinated stakeholders
- **Emergency response:** to deal with immediate and threatened access to communities and facilities
- **Vulnerable communities:** collaboration needed with them and amongst them to help maintain access. Through a consultation and information sharing programme a network of individuals and communities should be established to provide self-support and actions to help maintain accessibility throughout and post intense weather periods. Work plans and assistance programmes should be developed to assist those that are particularly vulnerable.
- **Isolated Communities:** contingency plans to be developed and temporary measures put in place to establish minimum access, possibly through diversions. Contingency plans may be temporary or permanent and will prioritise the most vulnerable socio-economic groups as well as transport.
- **Key A to B routes with active diversions:** to be deployed as part of a communication campaign. Temporary diversions to be developed and managed with active communication channels to deal with changing daily and weekly dynamics.

- **Routes closed for short/long periods and permanently:** contingency plans to be developed. Non-key routes might be left closed for temporary of extended periods during adverse weather periods.

The strategy for this scenario 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 then form the basis of a **cooperative communication and action campaign**.

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

- Developing 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;
- monitoring climate changes and their effects;
- address implications and consequences of doing little or nothing.

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

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. Evaluation of the monitoring should then be used to update the management plans.

3 Change Management

Change Management has the potential for making significant steps towards creating resilience to climate effects in a cost-effective way. It covers policy and planning, stakeholder and asset management and involves formulation of strategies and programmes for improvement. It also pays particular attention to management of measures that could be taken for a scenario where budgets are poor, inadequate or absent. Change Management options are often referred to as *non-engineering options* and consist of a range of policy and management improvements. Associated activities to address 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**.

3.1 Integrated approach

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

3.1.1 Identify and mobilise stakeholder and expertise involvement.

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

Recommended actions - Consult with relevant stakeholders from, amongst others, the following:

- Central government agencies that have a vested interest in road infrastructure planning and development
- National planning department
- National transport sector stakeholders, including road and transport ministries, departments and agencies/authorities (MDA's)
- Investors/funders of road asset projects
- Other relevant government ministries/ departments (e.g. agriculture, environment, science and relevant technology sectors)
- Climate change committees
- Multi-sectoral committees
- Institutes dealing with meteorology/hydrology (e.g. water resources, hydrology and flood control)
- Emergency services and or the national department dealing with disaster management
- Relevant businesses and NGO's
- Local level stakeholders directly affected by the activities of the project (this should go down all the way to affected village groups)
- District representative of central government agencies and departments with vested interest in road infrastructure planning and development (e.g. road and transport, disaster management, environment, agriculture, social and economic development, health, education)
- District road engineers

- Local level stakeholders directly affected by the activities (i.e. organisations involved in road construction and/or maintenance, community representatives, local government representatives that report to various district and central government departments and agencies)

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

Remarks considering a poor, inadequate or absent budget scenario

For planning, management and coordination purposes, the following stakeholders should also be engaged:

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

3.1.2 Improved network and programme management to anticipate and mitigate impacts

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

Recommended actions to enable more effective management of the network:

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

Information Box 3

Actions that the UK Highways England took to align strategies (Highways Agency, 2008):

- Aligned with the road authority's responsibilities and corporate objectives;
- Focused on the activities of the road authority, and how they need to change in response to a changing climate;
- Identifying priority areas for action;
- Integrated, where possible, with the ways in which the road authority fulfils its current responsibilities;
- Establishing clear responsibilities for developing and implementing adaptation actions in specific areas of activity, and also facilitating strategic oversight of progress and residual risk;
- Offering flexibility to enable the adaptation process to evolve and accommodate changing demands placed on the road authority, developments in climate science and the results of research and/or monitoring.

It may be prudent to appoint a **Climate Change Adaptation Programme Manager** who will have the responsibility for the overall management of the implementation of the Adaptation Strategy. Key responsibilities could include:

- monitoring legislative and other policy developments;
- developing training materials for technical and operational specialists;
- monitoring developments and updating climate trends information;
- maintaining the vulnerabilities schedule;
- dissemination and communication;
- agreeing an annual programme of work with asset managers for options analysis and the development of adaptation action plans; and
- producing activity and progress reports.

Remarks considering a poor, inadequate or absent budget scenario

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

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

3.1.3 Improved asset management resilience

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

The **following summary *activities are recommended*** *to improve resilience of the network:*

- Catalogue asset inventory
- Map, potentially using GIS, infrastructure assets in vulnerable areas; inventory assets that are susceptible to climate change impacts; collect elevation information as standard practice; use standard data collection systems between districts so that asset information can be compiled nationally
- Manage construction and operations to minimise effects of seasonal weather extremes
- Updating operating procedures to take account of the impacts of climate change. For example, updating the procedure for working in high temperatures
- Incorporate procedures to augment operational management and particularly for inadequate budget scenarios, covering:
    - Road weather programmes – with a means of sharing up-to-date information on the internet, via texting or mobile to a network of agreed contact points
    - Disaster preparedness planning – both with institutions and with communities
    - Alternative transportation access – agreed with formal and informal transport suppliers
    - Evacuation planning – at all levels from individuals, families, to whole communities with cross agreements between communities to help and support each other
    - Road user safety should also feature as a prominent issue in any climate change risk assessment and response strategy.

The safe protection of road workers should be managed, particularly during extreme weather events where they may be tasked to clear debris, redirect traffic or institute emergency repairs (PIARC, 2011).

3.1.4 Maintenance planning and early warning

Weather variability and the short and long-term effects of climate change will necessitate more frequent maintenance, rehabilitation and reconstruction of road infrastructure (e.g. access roads, geotechnical structures, bridges and drainage structures), as well as different design requirements, impacting on the budgets of road authorities.

Recommended actions:

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

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

Condition assessment and performance modelling will be improved by:

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

Recommended options for collaboration and cooperation are: (Gallivan et al., 2009):

- Establish or enhance cross-ministerial committees for managing adaptation to climate change, including for transport.
- Strengthen departments of disaster risk management and meteorology to improve information on which to make decisions.
- Introduce early warning and response systems for transport ministries to improve maintenance schedules and to respond quickly to post-disaster recovery needs.
- Promote low-risk adaptation strategies that will have development benefits regardless of the nature of climate changes that may take place. This is a useful approach where uncertainty is high regarding climate change and capital investments cannot be justified for large-scale infrastructural changes.
- Incorporate climate change adaptation into environmental impact assessments and strategic environmental assessment guidelines. This can take place specifically in the transport sector or, preferably, as part of the national standards. Road and transport ministries can test tools and adaptation approaches by applying strategic environmental assessments with climate change to their sector policies and plans.

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

3.1.5 Actions following a disaster event

The following specific stages of data collection are recommended following a shock event:

Stage 1: **Initial screening** for determining the functionality of the road network in terms of access and potential hazards. For example, some of the items being recorded at this point may include:

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

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

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

Table 4: Immediate Priorities following a disaster.

Priority	Objective	Priority	Road Network Function
High	Support Immediate Rescue	33%	Access & capacity
	Enable Support from other Areas	17%	Access
Medium	Support Lifelines	15%	Access
	Repair Key Infrastructure	14%	Wider mobility
Low	Facilitate Accessibility Between Communities	7%	Connectivity, access and capacity
	Protect Environment	6%	
	Protect Private Property	4%	
	Protect Economy	4%	

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

- **Planning stages (response, recovery, and rebuild) are distinct stages following a disaster -** Each one of these stages may include a full asset management cycle, although the planning time horizon of the stages are different:
    - Response – planning for the next hours and days;
    - Recovery – planning for weeks and months; and,
    - Rebuild – planning for the long-term, even longer than normal asset management cycles.
- **Chaos** - many post disaster reviews of major events often document the initial stages of the planning processes to be un-organised and fragmented. Having pre-event planning strategies in place assists bridging this stage quickly. Some of the pre-event planning strategies may include:
    - Where will the data be sourced from?
    - How to mobilise planning work forces?
    - Where is the most likely places where the planning will take place?
    - How will the planning processes be managed?
- **Nature of the disaster -** The nature and specific damage following a disaster will determine the planning needs;
- **Mobilisation of workforce** – The ability to get workforces mobilised is a significant challenge after major events as workers will also have their own families and properties to attend to;
- **Community involvement in decision making** - most disasters are often associated with significant tragic circumstances of loss of life, destroyed properties and the displacement of large numbers of people. Getting community involvement in the decision making and actual rebuilding is vital. This priority brings a specific need to the planning process, how it is done and how it is communicated;
- **Voluntary Sector, NGO's and charities –** agreement with key organisations what can be mobilised for different circumstances and how the chain of command will work
- **Police, military and emergency services -** agreement with key organisations what can be mobilised for different circumstances and how the chain of command will work
- **Build back better** - is a concept of ensuring the best outcome for the community when decisions are being made and often financial aspects becomes only one of the considerations. One of the main considerations during this stage is the balance between cost and future proofing;

3.1.6 Environmental management

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

Some biophysical drivers of vulnerability include poor land management, deforestation, slash and burn agriculture, monoculture cropping, slope instability, and geophysical instabilities. Some ecosystems, such as mountain ecosystems, are also inherently more sensitive to changes, while others are more exposed to climate changes and risks, such as low-lying coastal areas and desert

margins. Biophysical drivers that may exacerbate damages to roads and stream crossings are potentially numerous and may include the following:

- deforestation and loss of land cover;
- anthropogenic coastal and riverbank erosion;
- over-extraction of groundwater for domestic, agriculture, and/or industrial use; and
- ecological degradation caused by unsustainable development.

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

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

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

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

Adjustments can also be made to environmental management plans by selecting more drought- and heat-tolerant indigenous species during post-construction rehabilitation works or during maintenance works.

It is recommended that an integrated system approach is adopted. For example, design and implement ecosystem-based adaptation strategies focusing on environmental or green planning for project roads to improve flood and drought management. Climate-change resilient trees can be planted along embankments of all project roads with selected grass and biomaterials. The activity should take place after the roads have been paved, thus not obstructing roadwork during the rainy season.

Other improvements for flood and drought management include:

- Restoration of natural form and processes such as allowing streams and rivers to take natural courses;
- Use bioengineering and local plant species to prevent soil erosion.
- allowing unstable slopes to collapse and limiting shoreline armouring;
- restoring shorelines;
- creating drainage ponds and ecological overflow systems
- targeted removal of dikes
- drain wetlands.

Recommended actions for Road and Transport Ministries to incorporate appropriate adaptation measures into their implementation plans:

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

3.1.7 Hydrological management

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

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

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

During periods of heavy rainfall, the presence of water may cause impassable conditions, splash and spray, limiting visibility and increasing discomfort. This could have an impact on safety. Generally, roads are designed to transport water as quickly as possible from the road surface to the road verges and drainage systems. High precipitation rates especially in hilly areas can cause roads to have a thick surface water layer or even to be flooded to a certain extent, not only because the water cannot be transported quickly enough but also because water flows to the road from the surrounding environment. The latter especially transports not only water but also other materials, as mud, resulting in a drop of pavement friction (PIARC 2011).

Recommended actions:

- Inter-ministerial cooperation for riverine and water body management, including flood management and emergency controls
- International cooperation where major rivers cross more than one country

3.1.8 Augmenting standards and design guides

Most current Standards and National guides do not incorporate adaptation principles in any meaningful way. Investments in the transport sector are generally guided by a large number of design standards and regulations that in most cases are reflective of historical rather than future climate conditions. The revision of regulatory and design standards in the transport sector may significantly enhance the resilience of new transport sector investments to climate change. Ongoing dialogue with national transport sector stakeholders offers an opportunity to initiate such revision.

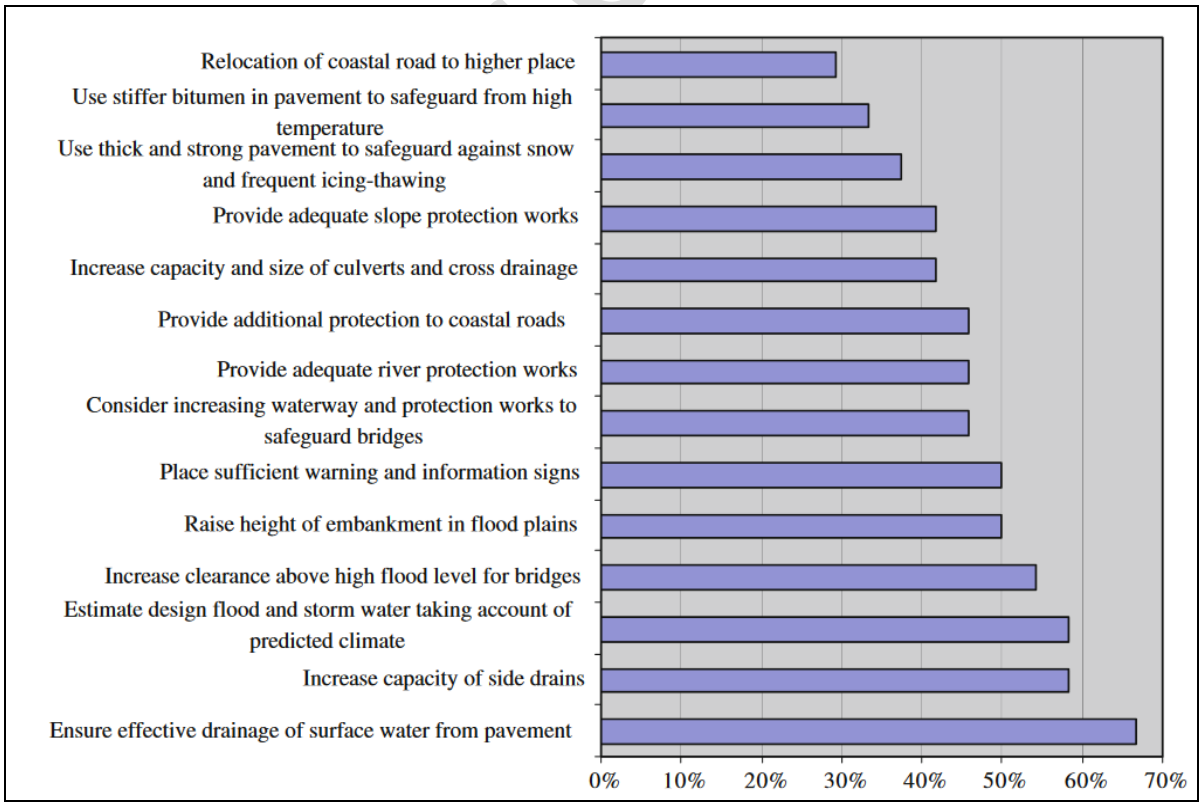
In some instances transport authorities have initiated a review of standards and design guidelines to incorporate issues of climate adaptation.

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

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

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

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



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

Recommended actions:

- Inspect all existing Standards, guides, manuals and similar publications/documents to determine whether climate threats and associated adaptation are adequately covered
- Determine which documents are being updated (or soon to be updated) and initiate actions to incorporate adaptation in their Terms of Reference
- For those for which there are no immediate plans to update, a decision should be taken whether to bring forward the update or whether to produce some form of augmentation.
- Form a multidisciplinary/multisector working group to scope out and deliver the necessary adaptation augmentation requirements based on the prioritisation set out above.

3.1.9 Road safety

Road user safety should feature prominently in any climate change risk assessment process. Risks that could be attributed directly to climate change effects include (PIARC, 2011):

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

Recommended actions:

- As part of normal network management, risk assessments are required. This activity should be augmented to cover additional risks from adverse weather and from adaptation activities.
- Road Safety Audits should be carried out for new construction programmes and these audits should be broadened to cover effects of adverse weather and the associated adaptation.

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

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

It is expected that, as a consequence of extreme climate effects, road pavements and other infrastructure may require more regular maintenance than is currently the norm. This may require road workers to work on the network more often and also may require them to work during

extreme climatic events; hence the need to also include the safety of road workers in the risk assessment process.

3.1.10 Research

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

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

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

Recommended actions include:

- Check with the National Research- and Tertiary Education institutions or Government archives on relevant research undertaken
- Coordinate or link planned climate adaptation research programmes in order to build competence and knowledge
- Collect experience and case studies for publication and dissemination

3.2 Managing the adaptation process

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

3.2.1 Adaptation options in the roads sector

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

- Avoiding areas projected to have a higher risk of potentially significant climate impacts is an important factor in planning decisions.
- If such locations cannot be avoided, steps need to be taken to ensure that the road infrastructure can withstand the projected changes. For example, the potential for increased flooding might be a reason to increase bridge elevations beyond what historic data might suggest. It should, however, be noted that most of the problems experienced are related to existing infrastructure that cannot be as easily relocated.

- 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 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. By increasing system resilience, even though a particular facility might be disrupted, the road network as a whole will still function.

The following are the primary engineering options:

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

3.2.2 Prioritisation of adaptation needs

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

Information Box 4

The World Bank's *Shock Waves* report (Hallegatte et al., 2016) 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. Some events considered exceptional today will become frequent in the long term, threatening current living conditions.
- These changes in hazards will affect poor people and the ability to eradicate poverty. Because poor people are often more exposed to natural hazards than the rest of the population, and

almost always lose a greater share of their assets and income when hit by a disaster, natural disasters will increase inequality and may contribute toward a decoupling of economic growth and poverty reduction.

- There are many options to reduce risks for poor people; and, although none are easy to implement, they do help reduce poverty and make the population more resilient to climate change. Examples include risk-sensitive land use regulation, more and better infrastructure, better housing quality and formal land tenure, air-conditioning, financial inclusion, and early warning and evacuation.

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

Information Box 5

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

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 the needs. 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.

Recommendations for prioritisation:

The following is a sequence in order of priority

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

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.

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

Table 5: Guidelines for Levels of Serviceability for mobility

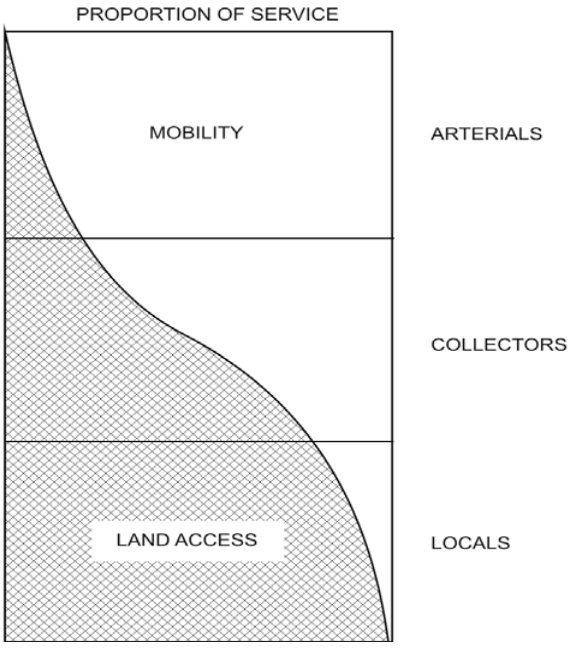
	Required standards for mobility		
Level of Serviceability	**Max Roughness (IRI units in m/km)**	**Impassability**	**Duration of impassability**
5	11	≯ than 4 days/yr	≯ than 1 day
4	9	Never	None
3	8	Never	None
2	7	Never	None
1	6	Never	None

Table 6: Guidelines for Levels of Serviceability for accessibility

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

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. Distinctions need to be made between those providing accessibility only as opposed to those providing predominantly mobility as shown in Figure 10.

Figure 10: Accessibility verses mobility for road type



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

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

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

Assessors carrying out the visual condition assessments will need to be aware of the possible national climate changes and make specific visual assessments of potential road and structure vulnerabilities. The following should be considered in this assessment:

- The degree of exposure of the road infrastructure to different climatic hazards;
- The sensitivity of the infrastructure to such changes in climate, and;
- The adaptations necessary to mitigate the potential for damage (inclusive of adaptive capacity).

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

One of the biggest challenges to making infrastructure more resilient is predicting the timing and quantum of climate changes in relation to the design/service life. An earth road may only have a design life of 5 or 6 years before significant upgrading is necessary. A large bridge on the other hand will be expected to provide good service for between 50 and 100 years, depending on its type. Whilst earth roads are likely to be highly vulnerable in places to climate impacts, the economic implications of these impacts would in most cases be negligible compared with those on structures such as bridges.

Recommended actions:

- Categorise relevant existing road network in terms of accessibility and mobility
- Optimise network re-categorisation for optimal accessibility through extreme anticipated weather cycles to be catered for
- Decisions on the classification of the level of serviceability should be based on a multi-criteria analysis and need to include issues such as social, traffic, connectivity and economic considerations.
- These analyses should be done at a strategic level. This will be based on the inventory of roads developed as part of the Road Asset Management System (RAMS) for any country as well as the existing condition, in order to identify any preliminary improvements.
- Assessors carrying out the visual condition assessments will need to be aware of the possible climate changes, which may vary from country to country, and make specific visual assessments of potential road and structure vulnerabilities based on the specific stressors identified for their individual countries or even regions within a country.

The following should be considered in this assessment:

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

In many cases, older engineered roads in a country's road network would be less affected by *gradual* changes in precipitation and temperature conditions. This is because these roads would more than likely have been upgraded or rehabilitated taking into account historical data on climate variability. However, the increase in extreme events that is expected to occur in the shorter term needs to be catered for on existing roads (and networks).

Information Box 6: Assessing cost options:

Each proposed project will need to be assessed in terms of the costs of adaptation versus the cost of doing nothing, taking into account all of the engineering, social and environmental costs and the discounted overall life-cycle costs to allow fair comparisons. The overall economic impacts are, however, expected to be massive. As an example, the World Bank has estimated that climate change has the potential to result in a $3.1 billion impact to roads in Ethiopia (through to 2100) when the effects of temperature, precipitation and flooding increases are taken into consideration (World Bank, 2010). They also indicate that 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)

Recommended actions to respond to various degrees of risk:

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

3.3 Embedment

Embedment aims to incorporate or place climate change issues in policies, strategies and plans, as well as in decision support systems such as Road Asset Management Systems. 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

3.4 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 (MDA's), and will include a wide range of participants from central government agencies cascading all the way through to village groups.

The following activities should be considered for systematic capacity building:

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

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

3. **Formulate a capacity development response**
   The capacity building response could be based on:
   - Leadership – high level involvement will help priority setting, communication and strategic planning;
   - Institutional arrangements – policies, procedures, resource management, organisation, leadership, frameworks, and communication;
   - Knowledge – the extent of knowledge on climate adaptation matters;
   - Accountability – the implementation of accountability measures facilitates better performance and efficiency.

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

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

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

a) Demonstration of engineering adaptation methodology on a project site creates the opportunity for local practitioners to become involved in site investigations, the identification of appropriate adaptation options (and the reasoning behind those), the design phase, the construction phase (with due attention devoted to quality of construction), and subsequent monitoring and evaluation;

b) 'Soft' demonstrators to guide practitioners through the processes of, for instance:

   - Identifying vulnerable districts and road links within a district, using the vulnerability assessment framework (see **Climate Threats and Vulnerability Assessment Guidelines**), and capacitate trainees to apply this methodology on a wider scale;
   - Embedding 'climate adaptation' in road asset management systems so as to support prioritisation and decision-making based on a broader spectrum of attributes, in addition to present road conditions. This will also require road condition assessors to be trained to identify potential environment-related risks and threats within and outside the immediate road environment.

c) Development of a dedicated training material on all aspect related to risk management and resilience optimisation, which could be used as a basis for the training of public and private sector practitioners in how to address climate variability and change.

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

- *Understanding* the challenges
- *Participation* and knowledge sharing/exchange
- *Agreeing* a methodology and programme for implementation climate adaptation
- *Developing* physical and social resilience
- *Disseminating* knowledge and experience

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

Recommended actions:

- High level government briefing and workshop to create awareness, understanding and shared responsibility to address climate change challenges
- Establish of a national climate adaptation department with a responsible officer.
- Produce standard training materials to be used by trainers across all MDA's and shareholders
- Establishment of a knowledge-exchange network (e.g. web-based) between organs of state, the private sector and academia; innovative aspects could include how to assess and manage current maintenance backlogs already caused by extreme climate effects;
- Participation in international knowledge-exchange networks, particularly those involved with dissemination of information
- Dissemination of potential options for climate adaptation and resilience strategies;
- Knowledge sharing/dissemination workshops; and national/regional/local training workshops

4 Approach and Delivery

4.1 Funding and climate vulnerability screening

Finding the necessary funding to implement climate resilience is one of the biggest challenges for road authorities. Funding is already, and has been for many years, insufficient to maintain the existing infrastructure. Response to current extreme events results in funding being diverted from other sources, usually from maintenance budgets, to "emergency" funds exacerbating the already underfunded maintenance requirements. Sourcing the necessary funds for climate resilience could thus be a major challenge for road authorities, and innovative funding pipelines would therefore have to be developed.

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. The following summarises recent strategies for multi-sectoral programmes and projects by development Partners (OECD, 2017):

World Bank Group

In line with the World Bank Strategy (2014), their fund for the poorest countries (International Development Association, IDA) now:

i) incorporates climate and disaster risk considerations into the analysis of development challenges and priorities, and, when countries agree, in the content of programmes and frameworks; and
ii) screens all new project and sectoral/national programmes for climate risks. The fund focusing on the private sector in developing countries (International Finance Corporation or IFC), and follows Performance Standards that define private sector client responsibilities for managing environmental and social risks, which include identifying climate risks and adaptation opportunities and promoting sustainable use of energy and water resources.

Asian Development Bank (ADB)

Since 2014, the ADB has institutionalised a framework to systematically identify proposed investments that may be adversely affected by climate change at the very early stages of project development and incorporate risk reduction measures in the project design. Guidelines for climate proofing investments for road transport have been in place since 2011. (Also see information box 7)

African Development Bank (AfDB)

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

European Bank for Reconstruction and Development (EBRD)

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

Nordic Development Fund (NDF)

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

Information Box 7

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

4.2 New infrastructure and structures

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

4.3 Rehabilitation and retrofitting

The application of adaptation measures to existing infrastructure is generally more difficult. However, most components of the infrastructure are designed to perform under the expected worst conditions and include some redundancy. Changing conditions are likely to occur periodically over time, mostly not exceeding the expected worst conditions. A well-designed road or structure, if properly maintained, should resist periodic extreme events with minimal damage.

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

During this process, as well as the routine visual condition and climate resilience assessments, other deficiencies that require improvement will normally be noticed. These will generally require more extensive work and resources and can then be included in plans for additional “retrofitting” as

funding permits. Visual assessment processes should consequently also be expanded to incorporate climate risk and vulnerability content

4.4 Maintenance

Weather variability and the short and long-term effects of climate change will necessitate more frequent, and probably different, maintenance of road infrastructure (e.g. access roads, geotechnical structures, bridges and drainage structures) impacting on the budgets of road authorities.

Recommended actions:

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

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

Condition assessment and performance modelling will be improved by:

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

4.5 Do-minimal approach

Do minimal can be expected to cause frequent disruptions to the infrastructure network and generally cost significantly more and take longer to restore passability. By necessity, this option is becoming much more prevalent as maintenance backlogs increase and funding becomes more problematic. Unfortunately, if it is part of a *reactive* management programme it becomes difficult to address affected communities in any realistic prioritisation programme. In many circumstances, there is just 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. Selection should then be on the basis of socio-economic effects and cost –benefit analysis. A planned programme of dialogue with affected communities, well dispersed information and contingency programmes are necessary to minimise the adverse effects of these decisions.

The consequences of insufficient emergency funds or backlog maintenance are that routine maintenance and/or planned rehabilitation is often suspended. Many African countries are experiencing chronic shortages of funds. In some cases, roads or structures are abandoned through

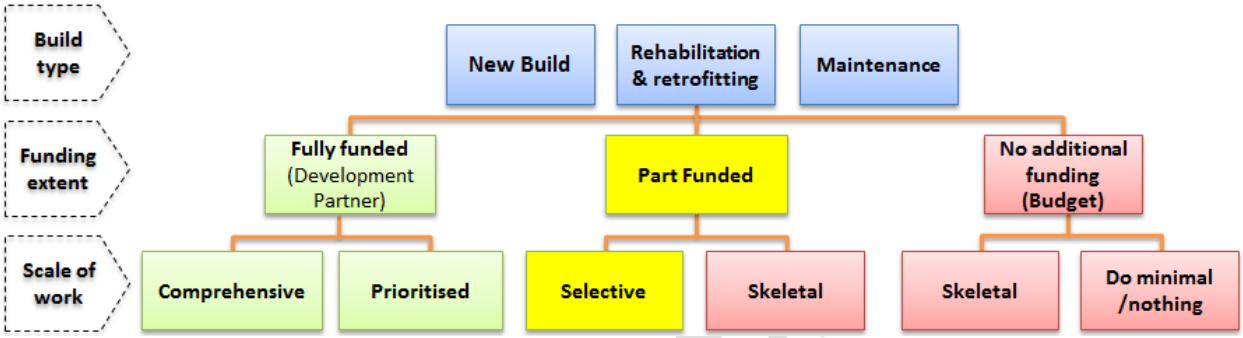
lack of funds or because of strategic decisions during adaptation prioritisation. In others, assets can be left impassable during rainy seasons or part thereof.

Where budgets are inadequate or absent the guidelines under the Inadequate Budget Scenario should be followed (see Sections 2.2.4 and Section 3).

4.6 Management of delivery

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

Figure 11: Hierarchy of delivery systems for climate resilience



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

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

Maintenance is generally entirely funded from local sources and is inevitably significantly underfunded (red in Figure 10). It is clear from the figure that usually only selected high-priority projects can be undertaken and the remainder of the infrastructure network would be subjected to reactive operations after climatic events. 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 a '*do minimal*' or *'No-Adapt'* scenario. It is recommended that, in these circumstances, the guidance set out in Sections 2.2.4 and throughout Section 3 is 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.

5 Effective Data Management

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

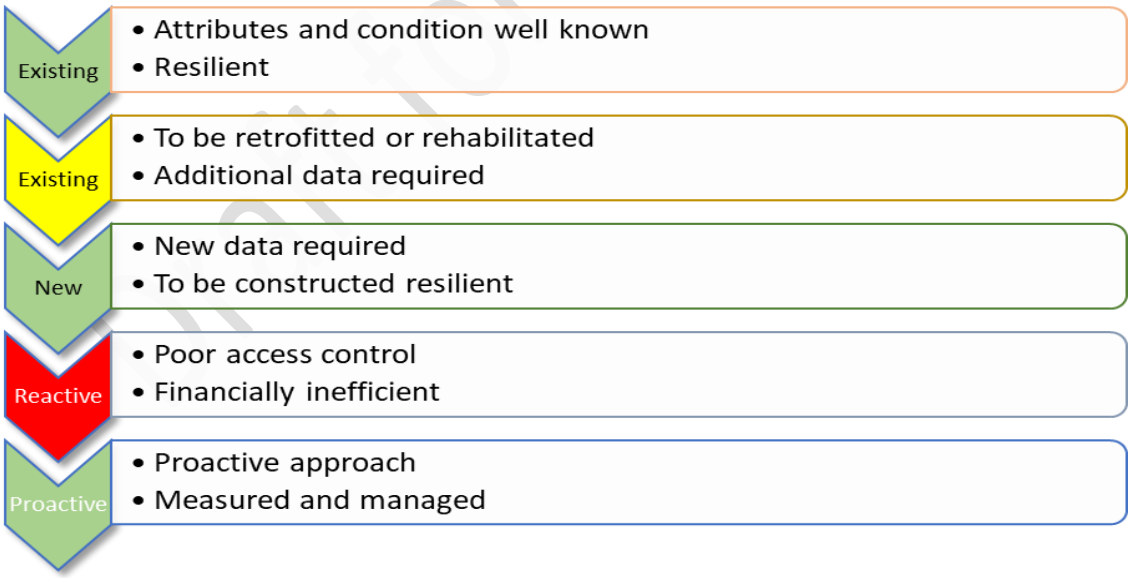
5.1 Data and Asset Management

Asset management is an overarching business model that provides the framework upon which climate change initiatives can be readily implemented into a road authority. Data on road and asset condition is not currently collected comprehensively or routinely in most sub-Saharan African countries. It is generally based on visual assessment with some measurements taken. Automatic data collection is rare.

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. This includes preparing in advance of the events; how to respond during an event; and what is to be rebuilt (and how it is rebuilt) after the event to ensure the network is more resilient before the next shock event occurs.

Figure 12 categorises assets into those not requiring adaption and those that will, it also reflects preferred philosophy for dealing with adaptation.

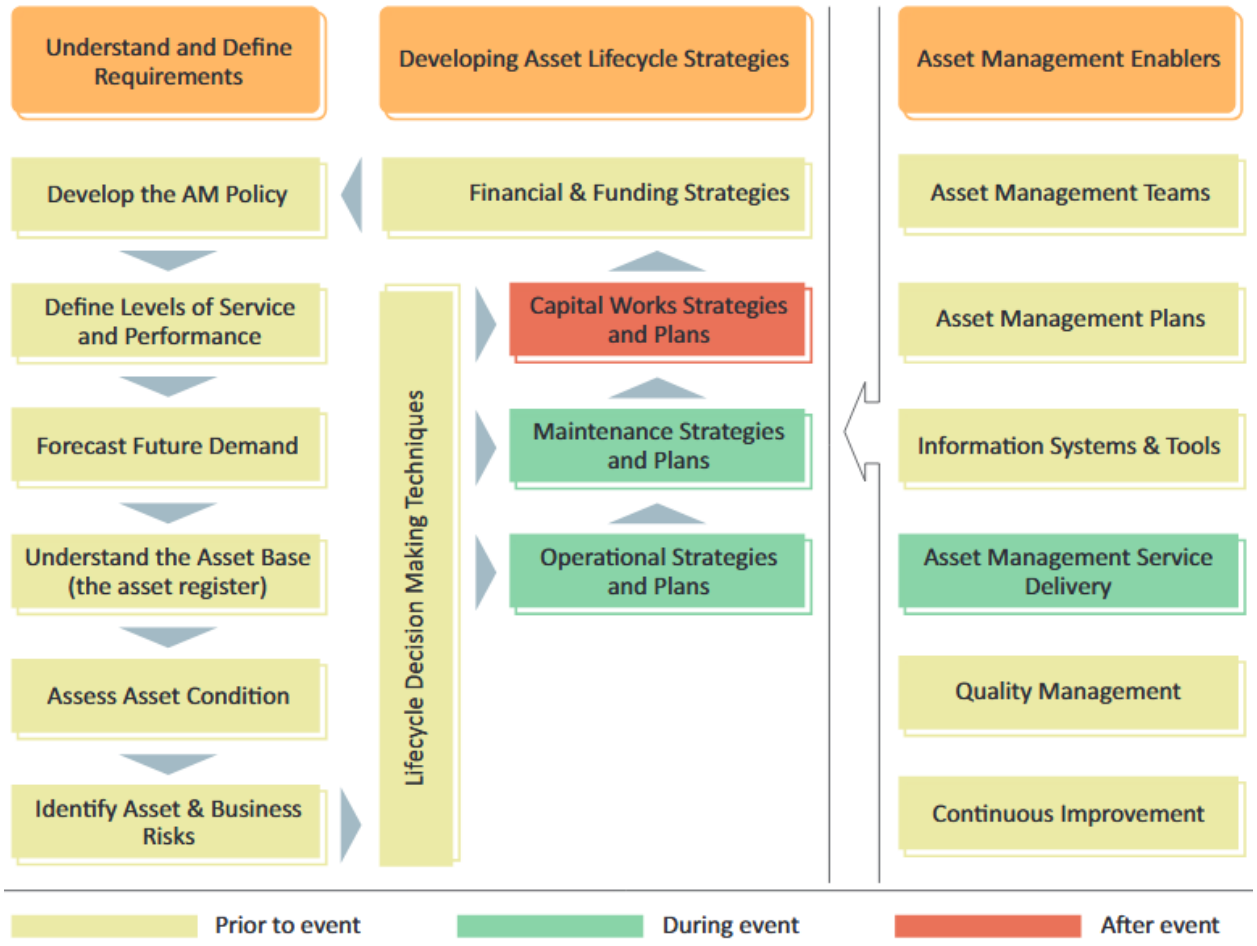
Figure 12: Assessment of assets for RAM for prioritisation and budgeting



The World Bank's Technical Report on Integrating Climate Change into Road Asset Management (Henning et al., 2017) guides road authorities on how to go about integrating climate change thinking into their business-as-usual asset management processes. It sets out how a typical Asset Management (AM) process should respond before, during and after a shock event; see Figure 13. Not all recommended actions will be applicable to all road authorities, although it is certainly

advisable to at least consider each within the overall asset management improvement process. In extreme cases these steps may go as far as abandonment of certain road assets that cannot be reasonably protected from climate change.

Figure 13: Asset management process versus response timing (NAMS, 2011)



The following three tables cover recommended actions to integrate climate change into Asset Management (AM) systems (Henning et al., 2017):

Table 7: Recommended actions to integrate change in AM practices (NAMS, 2011)

Phase	Step	Key Additional Actions
Understand and Define Requirements	**Develop the AM Policy**	• Specifically address climate change within the AM Policy statement, including what horizon is to be planned for • Have agreements in place on how the damage from major events will be funded and who will be entitled to financial support
	Define levels of service and performance	• Ensure network resilience measures (e.g. restore all major roads within 12 hours of end of 1:100year flood) are included into the level of service framework • Revise design guides to take into account the changing frequency of climatic events
	Forecast future demand	• Future demand forecast such as demographical changes and traffic loading increases should be integrated with climate change impacts on the expected performance of infrastructure • Providing for future growth in areas of high vulnerability should be avoided
	Understand the asset base	• Ensure that data on drainage assets and their vulnerabilities/ deficiencies is complete and up-to-date • All data collect ion processes should be geospatially referenced • Road data and information should highlight interdependencies with other infrastructure • Link life-lines and critical interactions between asset groups in the base data
	Assess asset condition	• Data collection should include measuring and recording of specific climatic effects on road network • Data collection techniques should also include the focus on quantifying the vulnerabilities of pavements to temperature and moisture changes
	Identify asset and business risks	• Ensure climate change is recognised as a risk to the asset and delivery of services • Risk and vulnerability assessments are already commonly used for climate adaptation. These processes should be integrated with risk management from an organisational risk perspective • The integration with asset management risk in particular promises significant efficiency gains …continue on next page…

Developing asset lifecycle strategies	Lifecycle decision making techniques	• Road asset management and systems brings a wealth of analytics to the climate adaptation topic area • Current analyses processes need to incorporate multi objective capabilities • More emphasis on community involvement in decision making is required when bringing climate adaption into the asset management decision making
	Operational strategies and plans	• Operational plans should include specific allowance for identifying and addressing deficient adaptation measures – such as making sure drainage structure are cleaned and without blockages • Include retrofitting infrastructure that is found to be significantly deficient • Trial new materials that may better resist climate change • Operational procedures should include policies and processes identified for responding to disasters
	Maintenance strategies and plans	• Maintenance strategies and plans should include specific allowance and focus on addressing items that limit the impact from climate change
	Capital works strategies and plans	• Updating of current design criteria (such as drainage design) is needed to allow for changing rainfall patterns • New designs should include specific consideration for climate adaptation technologies
	Financial and funding strategies	• Financial and funding strategies should investigate the impacts of different investment scenarios into climate adaptation • Financial and funding strategies should be in place for responding to potential disaster events
Asset management enablers	Asset management team	• Effective integration of climate adaptation and asset management must be driven from executive management levels within organisations • Appoint someone as the climate change champion to drive all these actions through the organisation
	Asset management plans	• Ensure that the AMP specifically addresses climate change
	Information management systems and tools	• Information management systems should be including the recoding of specific climatic and impact data for planning purposes • A data residence plan should be in place to respond to disaster planning needs
	Asset management service delivery/ Procurement	• Legislation and procurement processes should allow for the response to shock events
	Quality management	• Quality management of climate adaptation measures need to ensure its sufficient functioning
	Continuous improvement	• Identification of improvements necessary for climate change adaptation

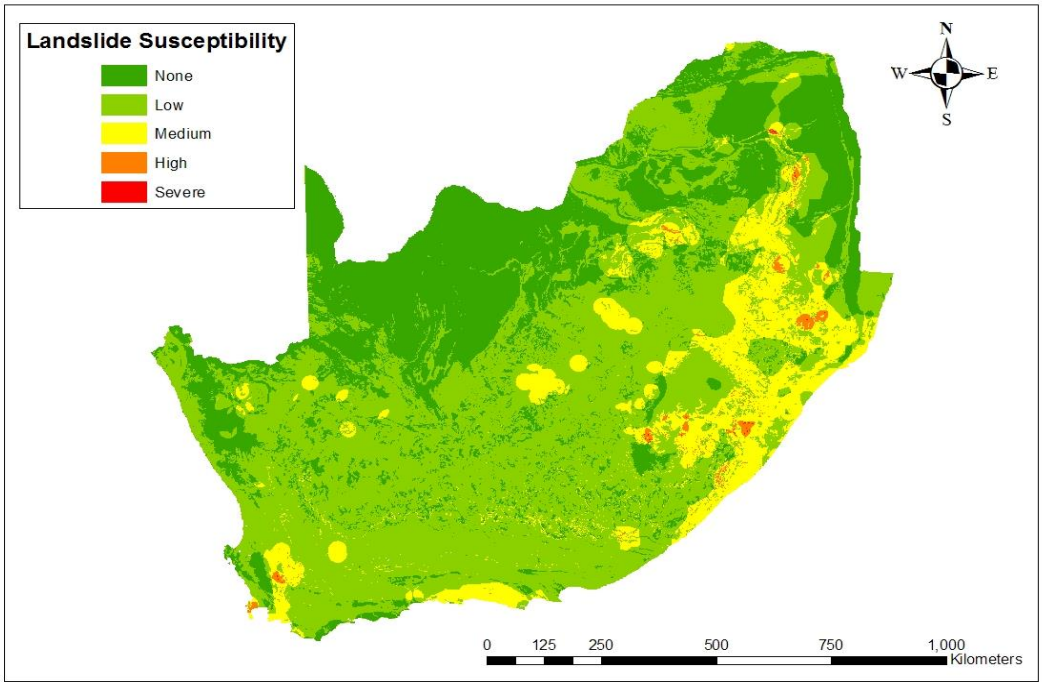
Table 8: Recommended adaptation strategies and monitoring techniques for the asset management system components (Ebinger and Vandycke, 2015)

Asset Management System Component	Monitoring Techniques and Adaptation Strategies
Goals and Policies	Incorporate climate change considerations into asset management goals and policies. These could be general statements concerning adequate attention of potential issues, or targeted statements at specific types of vulnerabilities (e.g., sea level rise).
Asset Inventory	Mapping of infrastructure assets in vulnerable areas, potentially using GIS. Inventory critical assets that are susceptible to climate change impacts.
Condition Assessment and Performance Modelling	Monitor asset conditions with environmental conditions (e.g., temperature, precipitation, winds) to determine if climate change affects performance. Incorporate risk appraisal into performance modelling and assessment. Identify high risk areas and highly vulnerable assets. Use "smart" technologies to monitor the health of infrastructure assets.
Alternatives Evaluation and Program Optimization	Include alternatives that use probabilistic design procedures to account for the uncertainties of climate change. Possible application of climate change-related evaluation criteria, smart materials, mitigation strategies, and hazard avoidance approaches.
Short- and Long-Range Plans	Incorporate climate change considerations into activities outlined in short and long range plans. Incorporate climate change into design guidelines. Establish appropriate mitigation strategies and agency responsibilities.
Program Implementation	Include appropriate climate change strategies into program implementation. Determine if agency is actually achieving its climate change adaptation/ monitoring goals.
Performance Monitoring	Monitor the asset management system to ensure that it is effectively responding to climate change. Possible use of climate change-related performance measures. Use "triggering" measures to identify when an asset or asset category has reached some critical level.

5.2 Slope management system

Where appropriate, it is also advisable to include, as part of the Asset Management System of all road authorities, a basic *Slope Management System* (SMS) that identifies the potential for failure and consequences of failure of all slopes within their jurisdiction. Such systems classify the stability of earth embankments and cut slopes, which allows those most likely to fail under extreme precipitation events to be prioritised for stabilisation interventions. It should be noted that such interventions are usually expensive and should be analysed and designed by experienced geotechnical engineers; general road practitioners are seldom sufficiently experienced to identify the optimum types of stabilisation measures or design their installation locations and properties. It is useful to integrate in, or develop independently of the SMS, slope failure incident maps. Landslide susceptibility can be represented as maps, as can be seen in Figure 14.

Figure 14: Example of a typical landslide susceptibility map for South Africa



Recommended actions for the introduction of a slope management system include:

- The assessment and identification of potentially unstable slopes.
- Prioritisation of high risk slopes requiring remedial action.
- Design of appropriate stabilisation measures as part of the climate resilience plan.
- Consideration should be given to the implementation of slope failure incident maps, either integrated in, or developed independent of an SMS.

5.3 Collect and analyse data and information

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

Recommended actions: assess following parameters and data:

- sea level and wave action (for coastal roads)
- precipitation intensity and slope (for mountainous regions)
- peak rainfall events (for designing drainage and protecting infrastructure)
- profiles of past extreme weather events
- changes to the onset of rainy seasons (for road maintenance and construction scheduling)
- wind speed (for erosion and wildfire hazard assessments).

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

5.3.1 Determine classifications and methods of assessment

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

As it is not economically possible to address every potential climate resilience problem, it is necessary to prioritise the roads within an area. 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.

The following should be considered in this assessment:

- The degree of exposure of the road infrastructure to different climatic hazards;
- The sensitivity of the infrastructure to such changes in climate, and;
- The adaptations necessary to mitigate the potential for damage (inclusive of adaptive capacity).

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

5.3.2 Method of assessment

To implement the necessary adaptations to make roads more climate resilient and assist with 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.

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

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

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

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

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

5.3.3 Role of assessors

Assessors carrying out the visual condition assessments will need to be trained and **aware of the possible local climate impacts** and make specific visual **assessments of potential road and structure vulnerabilities** based on the specific nationally agreed stressors.

Recommended considerations in this assessment are:

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

6 Climate Risk Screening

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

This Section refers to the **Climate Threats and Vulnerability Assessment Guidelines.**

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, climate vulnerability, threat and adaptation strategy provides strategic level support for national road and climate policies. At finer scales, regional and district level analyses 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.

6.1 Needs determination

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

- Climate Adaptation is often being addressed as part of a multi-sectoral National approach but transport and roads is not currently being included in any meaningful way.
- Climate risks and vulnerabilities need to be addressed.
- Relevant climate-related data need to be collected to support a new approach and has to be applied in the context of planning as well as linked to asset management systems.
- Appropriate new policies and strategies need to be embedded in plans, programmes and projects.
- Road damage backlogs from climatic effects are increasing at an alarming rate and need appropriate guidance to address.
- Maintenance budgets are not adequate to deal effectively with climate effects requiring better *return on Investment* and help with a *Do Nothing/Minimal* approach.
- Knowledge and capacity on climate adaptation need strengthening. In- country links with institutions dealing with climate change research is advisable.
-

Recommended actions:

- Carry out needs analyses within the Roads and Transport sector to identify what is the scope of the activities to be carried out and the outputs needed
- Consult with all relevant stakeholders so establish clear communication and cooperation lines
- Link or collaborate with other institutions dealing with climate change research

6.2 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 the course of the project to enable and support both

cross-disciplinary and inter-departmental coordination and collaboration amongst the public sector, private sector, and local stakeholders to assess impacts, vulnerabilities, and adaptation options.

Stakeholder communication and involvement should include a wide range of participants from central government agencies, all the way through to local communities. The district-level assessment may however, be most relevant to national or international stakeholders 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. Engaging stakeholders who are directly affected by the activities of the project allows for more effective decision-making as well as makes the development work process more transparent. The results of the district level assessment should be used to guide discussions around road adaptation prioritisation with relevant stakeholders.

Recommended actions:

1. Continuous engagement with a wide range of participants is recommended to ensure effective and efficient stakeholder communication, collaboration and involvement during the work process.

2. 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 department
- 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
- Relevant businesses and NGO's
- Local level stakeholders directly affected by the activities of the project (this should go down all the way to affected village groups)

6.3 Setting of policy, objectives and scope at network level

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

- Appoint a Climate Adaptation Programme Manager for implementation or task a responsible official
- 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.
- Ensure that asset management policy incorporate climate change adaptation to ensure its practical implementation in such systems
- 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.

7 References

African Development Bank (2009). Bank Group Climate Risk Management and Adaptation Strategy (CRMA).https://www.afdb.org/fileadmin/uploads/afdb/Documents/Policy-Documents/Climate Risk Management and Adaptation Strategy _CRMA_ %282%29.pdf

African Development Bank (2010). Climate Change Action Plan (CCAP) 2011-2015. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Policy-Documents/Climate Change Action Plan %28CCAP%29 2011-2015.pdf

Asian Development Bank (2011). Guidelines for Climate Proofing Investment in the Transport Sector: Road Transport Projects. Manila.

Asian Development Bank (2014). Climate Proofing ADB Investment in the Transport Sector: Initial Experience. Mandaluyong City, Philippines.

Bipartisan Policy Centre (BPC) (2010). Transportation Adaptation to Global Climate Change. Washington, DC.

Centre for Research on the Epidemiology of Disasters (CRED) and the United Nations Office for Disaster Risk Reduction (UNISDR) (2016). The Human Cost of Weather-related Disasters 1995-2015.

Chinowsky, P., Schweikert, A., Strzepek, N., Manahan, K., Strzepek, K. (2011). Adaptation advantage to climate change impacts on road infrastructure in Africa through 2100, WIDER Working Paper, No. 2011/25, ISBN 978-92-9230-388-4, The United Nations University World Institute for Development Economics Research (UNU-WIDER), Helsinki

Christensen, JH; Hewitson, B; Busuioc, A; Chen, A; Gao, X; Held, I; Jones, R; Kolli, RK; Kwon, W-T; Laprise, R; Magana Rueda, V; Mearns, L; Menendez, CG; Raisanen, J; Rinke, A; Sarr, A and Whetton, P (2007). Regional climate projections. In: Solomon, S; Qin, D; Manning, M; Chen, Z; Marquis, M; Averyt, AB; Tignor, M and Miller, HL (eds). Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Inter-governmental Panel on Climate Change. Cambridge University Press, Cambridge.

Ebinger, JO and Vandycke, N (2015). Moving Toward Climate-Resilient Transport. The World Bank's Experience from Building Adaptation into Programs. The World Bank Group, Washington DC.

Engelbrecht, FA; McGregor, JL and Engelbrecht, CJ (2009). Dynamics of the conformal-cubic atmospheric model projected climate-change signal over southern Africa. Int J Climatol 29 1013–1033.

Engelbrecht, CJ; Engelbrecht, FA and Dyson, LL (2013). High-resolution model projected changes in mid-tropospheric closed-lows and extreme rainfall events over southern Africa. Int J Climatol 33 173–187. doi:10.1002/joc.3420.

Engelbrecht, F; Adegoke, J; Bopape, MM; Naidoo, M; Garland, R; Thatcher, M; McGregor, J; Katzfey, J; Werner, M; Ichoku, C and Gatebe, C (2015). Projections of rapidly rising surface temperatures over Africa under low mitigation. Environmental Research Letters. Submitted.

Gallivan, F; Ang-Olson, J and Turchetta, D (2009). Integrating Climate Change into State and Regional Transportation Plans. Seminar paper submitted for presentation at the Transportation Research Board annual meeting and publication in the Transportation Research Record.

Hallegatte, S; Bangalore, M; Bonzanigo, L; Fay, M; Kane, T; Narloch, U; Rozenberg, J; Treguer, D; Vogt-Schilb, A. (2016). Shock Waves : Managing the Impacts of Climate Change on Poverty.

Climate Change and Development. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/22787 License: CC BY 3.0 IGO.

Head, M; Verhaeghe, B; Paige-Green, P; le Roux, A; Makhanya, S and Arnold, K (2018). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: Climate Adaptation Handbook, GEN2014C. London: ReCAP for DFID.

Henning, TFP; Tighe, S; Greenwood, ID; Bennett, CR. (2017). Integrating climate change into road asset management: Technical report 2017. Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/981831493278252684/Technical-report-2017

Highways Agency (2008). Climate Change Adaptation Strategy: Volume 1. Department for Transport, United Kingdom.

Hughes, G; Chinowsky, P and Strzepek, K (2010). The Cost of Adapting to Climate Change for Infrastructure. Discussion Paper No.2. Washington, D.C.: World Bank Group.

James, R and Washington, R (2013). Changes in African temperature and precipitation associated with degrees of global warming. Climatic Change 117 859–872. DOI 10.1007/s10584-012-0581-7.

Le Roux, A; Makhanya, S; Arnold, K and Mwenge Kahinda, JM (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.

Lyon, B and DeWitt, DG (2012). A recent and abrupt decline in the East African long rains. Geophys. Res. Lett. 39 L02702, doi:10.1029/2011GL050337.

Malherbe, J; Engelbrecht, FA and Landman, WA (2013). Projected changes in tropical cyclone climatology and landfall in the Southwest Indian Ocean region under enhanced anthropogenic forcing. Clim Dyn 40 2867–2886.

NAMS (2011). International Infrastructure Management Manual. (International ed., 4th ed) Institute of Public Works Engineering Australia. Wellington, N.Z.: National Asset Management Steering NAMS Group.

Niang, I; Ruppel, OC; Abdrabo, M; Essel, A; Lennard, C; Padgham, J; Urquhart, P; Adelekan, I; Archibald, S; Barkhordarian, A; Battersby, J; Balinga, M; Bilir, E; Burke, M; Chahed, M; Chatterjee, M; Chidiezie, CT; Descheemaeker, K; Djoudi, H; Ebi, KL; Fall, PD; Fuentes, R; Garland, R; Gaye, F; Hilmi, K; Gbobaniyi, E; Gonzalez, P; Harvey, B; Hayden, M; Hemp, A; Jobbins, G; Johnson, J; Lobell, D; Locatelli, B; Ludi, E; Otto Naess, L; Ndebele-Murisa, MR; Ndiaye, A; Newsham, A; Njai, S; Nkem, Olwoch, JM; Pauw, P; Pramova, E; Rakotondrafara, M-L; Raleigh, C; Roberts, D; Roncoli, C; Sarr, AT; Schleyer, MH; Schulte-Uebbing, L; Schulze, R; Seid, H; Shackleton, S; Shongwe, M; Stone, D; Thomas, D; Ugochukwu, O; Victor, D; Vincent, K; Warner, K and Yaffa, S (2014). IPCC WGII AR5 Chapter 22 pp 1-115.

OECD (2009). Integrating Climate Change Adaptation into Development Co-operation. Paris: Organisation for Economic Co-operation and Development.

OECD (2017). Lola Vallejo and Michael Mullan. Climate-Resilient Infrastructure: Getting the Policies Right - Environment Working Paper No. 121.

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.

PIARC (2011). Dealing with the Effects of Climate Change on Roads, 2012R06EN. Paris: World Road Association.

Regmi, M and Hanaoka, S. (2011). A Survey on Impacts of Climate Change on Road Transport Infrastructure and Adaptation Strategies in Asia. Environmental Economics and Policy Studies. 13. pp. 21–41.

Roehrig, R; Bouniol, D; Guichard, F; Hourdin, F and Redelsperger, JL (2013). The present and future of the West African monsoon: a process-oriented assessment of CMIP5 simulations along the AMMA transect. Journal of Climate doi:10.1175/JCLI-D-12-00505.1.

United Nations, Department of Economic and Social Affairs, Population Division (2018). World Urbanization Prospects: The 2018 Revision, Online Edition.

Williams, AP; Funk, C; Michaelsen, J; Rauscher, SA; Robertson, I; Wils, THG; Koprowski, M; Eshetu, Z and Loader, NJ (2012). Recent summer precipitation trends in the Greater Horn of Africa and the emerging role of Indian Ocean sea surface temperature. Climate Dynamics 39 2307-2328.

World Bank (2010). Ethiopia - Economics of adaptation to climate change: Main report (English). Washington, DC: World Bank. http://documents.worldbank.org/curated/en/310391468340238724/Main-report

World Bank (2014) Climate and disaster risk screening tools. Accessed from site: https://climatescreeningtools.worldbank.org on 1 July 2018.

World Bank (2017). Climate Change and Asset Management. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO