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

Sixth Quarterly Progress Report

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

AfCAP Project GEN2014C

February 2018

Verhaeghe, B., Makanya, S., Kombo, J., Paige-Green, P., Maritz, J., Le Roux, A. (2019). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa, Sixth Quarterly Progress Report, GEN2014C. London: ReCAP for DFID.

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Quality assurance and review table

Version	Author(s)	Reviewer(s)	Date
1	Verhaeghe, B., Makanya, S., Kombo, J., Paige-Green, P., Maritz, J., Le Roux, A.	N Leta, ReCAP PMU	28.02.2019

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

Reference No:	GEN2014C	Location	Sub-Saharan Africa
Source of Proposal	DFID/ReCAP	Procurement Method	Tender
Theme	Sustainability of access	Sub-Theme	Climate resilience
Lead Implementation Organisation	CSIR	Partner Organisation	Paige-Green Consulting St Helens Consulting
Start Date	May 2017	End Date	May 2019 (Amendment no. 1)
Report Due Date	February 2019	Date Received	February 2019

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Abstract

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.

In order to help address this significant threat to Africa's development, the Africa Community Access Partnership (AfCAP), a research programme funded by UKAid, has commissioned a project that started in April 2016 and is expected to be completed by December 2018, 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 to deal with the effects of climate on their low-volume access roads; (c) sustainable enhancement in the capacity of additional AfCAP partner countries; and (d) uptake and embedment across AfCAP partner countries.

This sixth Quarterly Progress Report outlines the progress that has been made since the fifth Quarterly Progress Report of September 2018, i.e. it covers the period from September 2018 to February 2019. It primarily focusses on the following activities/events: (a) progress on the establishment of demonstration sections in Mozambique; (b) embedment workshop held in Ghana; (c) status of the climate adaptation handbook, guidelines and manual; (d) development of a quantified Vulnerability Index; (e) knowledge dissemination; (f) status of the country reports; (g) preliminary work plan for Phase 3; and (h) preliminary cost-benefit analysis for the AfCAP Climate Adaptation project.

Key words

Change Management, Climate Adaptation; Climate Change; Climate Impact; Climate Threat; Climate Vulnerability; Rural Access; Resilience; Vulnerability

Research for Community Access Partnership (ReCAP)

Safe and sustainable transport for rural communities

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

www.research4cap.org

Glossary (within the context of this project)

Adaptation	Autonomous or policy-driven adjustments in practices, processes or structures to allow for 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 the safety of populations and the 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 to enhance the strengths and attributes of, as well as resources available to, an individual community, society or organisation in response to change.
Change Management	A collective term for all approaches towards preparing and supporting individuals, teams and organisations in making organisational or institutional changes to equip them to address and resolve new or recurring challenges that affect 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 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 in 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 society due to hazardous physical events interacting with vulnerable social conditions. This leads to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs. It may also 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 for 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, trend or 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 and their physical impacts.
Impacts (Consequences, Outcomes)	Effects on natural and human systems. In this report, the term *impacts* is used primarily to refer to the effects of extreme weather and climate events and of climate change on natural and human systems. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure, due to climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts and sea level rise, are a subset of impacts called physical impacts.
Impact Assessment	The practice of identifying and evaluating, in monetary and/or nonmonetary terms, the effects of [climate] change on natural and human systems.
Likelihood	The chance of a specific outcome occurring, where this might be estimated probabilistically.
Mitigation	The alleviation 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, trend or disturbance; to respond or reorganise 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 exposed system and that can increase vulnerability to climate-related risk.
System Sensitivity	The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise).
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
Vulnerability Assessment	Process that attempts to identify the root causes of a system's vulnerability (to climate variability and change).

Acronyms, Units and Currencies

ADB	Asian Development Bank
AfCAP	Africa Community Access Partnership
AfDB	African Development Bank
ANE	Administração Nacional de Estradas (National Roads Administration, Mozambique)
AsCAP	Asia Community Access Partnership
CAPSA	Conference on Asphalt Pavements for Southern Africa
CBA	Cost-Benefit Analysis
CEDR	European Conference of Directors of Roads
DFR	Department of Feeder Roads, Ghana
ERA	Ethiopian Roads Authority
EU	European Union
GDP	Gross Domestic Product
GEM	Growth through Effective Road Asset Management
GIS	Geographic Information System
IRF	International Road Federation
KTC	Koforidua Training Centre (Ghana)
LVR	Low-Volume Road
NDF	Nordic Development Fund
PIARC	World Road Association
PIT	Project Implementation Team (GEM)
PMU	Programme Management Unit, ReCAP
RAI	Rural Accessibility Index
RAMS	Road Asset Management System
ReCAP	Research for Community Access Partnership
SARF	South African Road federation
SDG	Sustainable Development Goal
TRB	Transportation Research Board
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)
USD	United States Dollar

Executive summary

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

In order to help address this significant threat to Africa's development, the Africa Community Access Partnership (AfCAP), a research programme funded by UKAid, commissioned a project in April 2016 to produce regional guidance on the development of climate-resilient rural access in Africa through research and knowledge sharing within and between participating countries. Research is being conducted on appropriate and economic methodologies for risk and vulnerability assessments; prioritisation of adaptation interventions; and optimisation of asset resilience in the context of rural access. In addition, evidence of cost, economic and social benefit links to rural communities arising from more resilient rural access will be required to support wider policy adoption across Africa.

Previous outputs from this project included an overview of current and projected climate threats and their impact on low-volume road infrastructure particularly in AfCAP partner countries; risk and vulnerability assessment methodologies; adaptation methodologies; and engineering and non-engineering adaptation options. Preliminary work was also done to establish demonstration sections in three Lead Countries, namely Ethiopia, Ghana and Mozambique, followed by workshops held in these countries. The purpose of these workshops was to assess these outputs as well as to identify the countries' priorities for uptake and embedment.

The current focus of the project is on demonstrations of appropriate practices, capacity building, and the uptake and subsequent embedment of outcomes at a range of levels, from informing national policies, through regional and district planning, down to practical guidance on adaptation delivery at rural road level. The demonstrations will largely focus on demonstrating the vulnerability assessment and climate adaptation methodologies.

This sixth Quarterly Progress Report presents the progress made since September 2018. The following were achieved during this quarter:

a) Establishment of demonstration sections in Mozambique which are near completion

b) Training of local engineers in Ghana on technique to identify the vulnerability of road assets to climate and to identify remedial actions to render these assets climate resilient

c) Updating of the Climate Adaptation Handbook, associated guidelines and visual assessment manual (uploaded to the ReCAP website)

d) Development of a draft quantified Vulnerability Index (for discussion)

e) Successful presentation of papers at the AfricaGeo (September 2019) and the SARF/IRF/PIARC conference (October 2019), and preparation of papers for PIARC, CAPSA and other events;

f) Production of final drafts of the Country Reports for the three AfCAP Lead Countries, which have been reviewed by the Lead Countries;

g) Development of a preliminary work plan for Phase 3.

h) First-level cost-benefit analysis for the AfCAP Climate Adaptation project.

1 Background

1.1 Brief introduction to the programme and beneficiaries

The Africa Community Access Partnership (AfCAP) is a programme of applied research and knowledge dissemination funded by the UK Government though the Department for International Development (DFID). AfCAP is promoting safe and sustainable rural access in Africa through research and knowledge-sharing between participating countries and the wider community.

The proposed main beneficiaries of this Regional Project are the AfCAP partner countries, which currently consist of the Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Liberia, Malawi, Mozambique, Sierra Leone, South Sudan, Tanzania, Uganda and Zambia. The main focus is on low-volume road network and transport services that serve rural communities.

The AfCAP partner countries are shown in Figure 1.

Figure 1 AfCAP partner countries

1.2 Delivery organisations

The delivery organisation of the project is a Consortium consisting of the Council for Scientific and Industrial Research (CSIR), Paige-Green Consulting (Pty) Ltd and St Helens Consulting Ltd. The Consortium is led by CSIR.

1.3 Key dates

The period of implementation of this project is 33 months, from April 2016 to May 2019. It is conducted in two phases:

- Phase 1: April 2016 to February 2017 (11 months)
- Phase 2: May 2017 to May 2019 (25 months; previous completion date of December 2018 has been extended)

2 Project Background

2.1 General

Africa is experiencing more extreme climate events such as droughts, floods, storms and cyclones. Dramatic changes to the continent's climate is causing widespread damage to road infrastructure and its associated assets. Rural accessibility is being compromised in a number of countries and sub-regions for increasing proportions of the year, with both direct and indirect adverse effects on livelihoods and associated socio-economic development.

In order to help address this significant threat to Africa's development, the Africa Community Access Partnership (AfCAP), a research programme funded by UKAid with the aim of promoting safe and sustainable transport for rural communities in Africa, 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. Research is being conducted on appropriate and economic methodologies for risk and vulnerability assessments; prioritisation of adaptation interventions; and optimisation of asset resilience in the context of rural access. In addition, evidence of cost, economic and social benefit links to rural communities arising from more resilient rural access will be required to support wider policy adoption across Africa. The evidence, through a cost-benefit analysis, is to be presented in the final report, although a preliminary analysis is presented in this report.

The project is being implemented in two Phases. The focus of Phase 1 (April 2016 to April 2017) was primarily on the establishment of an approach to climate adaptation through research and knowledge exchange. A further aim was to provide consensus for the implementation of demonstration sections in Ethiopia, Ghana and Mozambique, and to deliberate on the initial guideline documents produced at workshops held in these three countries.

Outputs from Phase 1 addressed current and projected climate threats and their impact on low-volume road infrastructure; risk and vulnerability assessment methodologies; adaptation methodologies; and engineering and non-engineering adaptation options. Preliminary work was also done to establish demonstration sections in three lead countries, namely Ethiopia, Ghana and Mozambique, followed by workshops held in these countries. The purpose of these workshops was to assess these outputs as well as to identify the countries' priorities for Phase 2 of this project.

Phase 2 (May 2017 to December 2018) has focused mainly on demonstrations of appropriate practices, capacity building, and the uptake and subsequent embedment of outcomes at a range of levels, from informing national policies, through regional and district planning, down to practical guidance on adaptation delivery at rural road level. The demonstrations will largely focus on the vulnerability assessment and climate adaptation methodologies.

During Phase 2, synergies are being sought with relevant Development Partners' programmes such as those in Ethiopia (World Bank), Kenya (World Bank), Mozambique (EU, NDF, World Bank) and Tanzania (DFID, EU), focussing on programmes that are aligned with the general objectives of this project. This is considered important to prevent duplication of efforts and to harmonise approaches that could be deployed across the sub-Saharan region. The stated Development Partners have requested and been provided the current draft Guidelines to inform their own programmes in the lead countries.

There is a possibility that a third phase will be approved for this project. The objective of Phase 3 will be to disseminate climate resilient methodologies, technologies and solutions to all ReCAP Partner Countries (i.e. in Africa and Asia) and to capacitate these countries (cf. Section 8).

2.2 Research objectives

The overall project objectives remain as follows (quoted from the project's Terms of Reference):

- *The fundamental research objective of this 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*
- *Capacity Building and Knowledge Exchange. The appointed consultants must engage meaningfully, from project inception onwards, with relevant partner-country Road and Transport Ministries, Departments and Agencies/Authorities in a knowledge dissemination and capacity building programme based on the outputs from the research. Capacity building should include a wide range of targets from central government agencies to village groups.*
- *Uptake and Embedment are integral elements of this project. The appointed consultants must ensure that there is focus on uptake and subsequent embedment of outcomes. This must be aimed at a range of levels from informing national policies, through regional and district planning, down to practical guidance on adaptation delivery at rural road level.*

2.3 Scope of Phase 2

The following five distinct parts have been adopted for Phase 2, reflecting the programme's aim and objectives (cf. Inception Report for Phase 2 (Verhaeghe et al, 2017a) for more information on the methodology and programme):

1. **PART A:** *Demonstrate appropriate engineering and non-engineering adaptation procedures*

   Identify, characterise and demonstrate appropriate engineering and non-engineering adaptation procedures that may be implemented to strengthen the long-term resilience of rural access. Assess the socio-economic impacts of adopting more climate resilient adaptations.

2. **PART B:** *sustainable enhancement in the capacity of three AfCAP partner countries*

   Engage meaningfully, from project inception onwards, with relevant partner-country Road and Transport Ministries, Departments and Agencies/Authorities in a knowledge dissemination and capacity building programme based on the outputs from the research. Capacity building should include a wide range of targets from central government agencies to village groups.

3. **PART C:** *sustainable enhancement in the capacity of additional AfCAP partner countries*

   Carry out situational analysis and initiate capacity building programme in additional countries.

4. **PART D:** *uptake and embedment across AfCAP partner countries*

   Uptake and embedment will assume the format of informing national policies, through regional and district planning, down to practical guidance on adaptation delivery at rural road level.

5. **PART E:** *Phase 3 recommendations*

   Set out costed long-term monitoring and evaluation proposals, as well as any future actions that may be required to strengthen uptake and embedment.

Chapters 4 to 8 of this report address the progress achieved on Parts A to E, respectively, since the 5th Progress Report (Verhaeghe et al, 2018c).

3 Overview of Previous Progress Reports

Table 1 presents an overview of the project activities reported in the Inception Report and subsequent Progress Reports for the period April 2017 to May 2018.

Table 1 Project Activities reported in previous Progress Reports

Document/Period (Reference)	Activities Reported
Inception Report Apr to Jun 2017 (Verhaeghe et al., 2017a)	– Outcomes of two workshops: (a) Tanzania Stakeholder Workshop (April 2017), and AfCAP Workshop held at the 8th Africa Transportation Technology Transfer Conference held in Zambia in May 2017 – Methods and/or screening tools used by the World Bank, the EU, the European Conference of Directors of Roads (CEDR) and the Asian Development Bank (ADB) for mapping climate vulnerability regionally, nationally and locally, and benchmarking of the method proposed by the AfCAP Project Team against these four methods – Progress on drafting of a generic Handbook outlining the climate adaptation methodology, as well as on guidelines for non-engineering adaptation measures.
1st Progress Report Jun to Aug 2017 (Verhaeghe et al., 2017b)	– Progress on the establishment of demonstration sections – The development of a climate threat and vulnerability methodology for application at a local/project level – The development of the draft *Climate Adaptation Handbook* and the three associated guidelines, namely *Change Management Guidelines*, *Climate Threats and Vulnerability Assessment Guidelines*; and *Engineering Adaptation Guidelines*.
2nd Progress Report Aug to Nov 2017 (Verhaeghe et al., 2017c)	– Progress on the establishment of demonstration sections – Further progress made on a climate threat and vulnerability assessment methodology – Feedback on the workshop held in Mozambique in September 2017 – The adaptation of conventional asset management practices to incorporate climate effects – The status of the country progress reports primarily focussing on the aspects of change management.
3rd Progress Report Nov 2017 to Feb 2018 (Verhaeghe et al., 2018a)	– Progress update on demonstration sections – Feedback on workshops held in Ethiopia and Ghana – Updating of the Climate Risk and Vulnerability Assessment Guideline, and modification of the Handbook and Change Management Guidelines by the incorporation of the 'do nothing' strategic option – Status of the Country Reports for the three Lead Countries – Report back to the 1st Inter-Regional Implementation Meeting held in Uganda
4th Progress Report Mar 2018 to May 2018 (Verhaeghe et al., 2018b)	– Progress update on demonstration sections – Embedment workshops and meetings held in Mozambique – Updating of the Engineering Adaptation Guideline – Second draft of Mozambican Country Reports – Report back on poster presentation at the Gender Summit 14 – Africa (Climate Change through the Gender Lens – Focus on Africa) held in Kigali, Rwanda.

Document/Period (Reference)	Activities Reported
5th Progress Report Jun 2018 to Sep 2018 (Verhaeghe et al., 2018c)	– Progress update on demonstration sections and associated embedment activities (Ethiopia) – Addition of the Visual Assessment Manual to the suite of Handbook and Guidelines produced – Trialling of the vulnerability assessment method and Visual Assessment Manual in Ethiopia – Embedment workshops and meetings held in Ethiopia and Ghana – Preparation of papers for conferences

4 Activity Progress: Demonstrations (Part A)

4.1 Mozambique

It was reported in the 5th Progress Report (Verhaeghe et al., 2018c) that construction of the four demonstration sections on the Mohambe to Maqueze road had not yet been initiated. However, construction has since started and is progressing well. It is estimated that all four demonstration sections will be completed by end-March 2019.

The Project Team undertook two visits to the road since construction started, namely: between 8 and 12 October 2018 and between 4 and 7 December 2018. The final visit is planned to take place from 10 to 14 March 2019.

A design and construction report for demonstration sections on the Mohambe to Maqueze road has been drafted and is being updated on a continuous basis with latest information obtained from the site. It is expected that the report will be finalised by mid-April 2019. It will address the following:

- Observations
    - September 2016 visit
    - August 2017 Visit
- Problems identified during site visits
    - Erosion and undercutting of concrete fords
    - Damage to culverts and erosion protection
    - Damage to road surface
    - Ineffective drainage of road surface – poor shape and side-drains
- Design and construction (two separate chapters)
    - Undercutting of concrete fords
    - Damage to road approaching concrete ford
    - Damage to culverts and erosion protection
    - Improved gravel road
    - Recommendations

The current status of construction based on the observations made by the Project Team during their two site visits is presented in Annex 1.

Some of the photographs taken before construction (August 2017) and during construction (December 2018) of the four demonstration sections are shown in Figure 2.

Figure 2 Construction of demonstration sections (work in progress)

Section	August 2017	December 2018
Concrete fords (km 17.6)		

Section	August 2017	December 2018
Road approaching concrete ford (km 36)		
Culvert and erosion protection (km 43)		 
Improved gravel road (km 51)		

4.2 Ghana

4.2.1 Purpose and background of training/embedment initiative

A visit to Ghana was carried out by Dr P Paige-Green between the 30th of October and 2nd of November 2018. The aim of the trip, similar to the one that was undertaken to Ethiopia and reported by Verhaeghe et al (2018c), was to carry out trialling of the vulnerability assessment method and the newly-developed visual assessment manual, and to train local engineers from various road departments in Ghana in the purpose and technique of vulnerability assessments for climate resilience. It was envisaged that some of these engineers would ultimately become trainers and train sufficient engineers from each Region and District to carry out such assessments in order to expedite the process in Ghana. The fact that two of the twelve participants were from the Koforidua Training Centre (KTC) is a strong indication of the importance attached to the exercise and the potential for the KTC to be strongly involved in future training.

Twelve Engineers were identified by Ghana Feeder Roads and Highways and attended all of the field work. Their names and affiliations are provided in Annex 2. The engineers were divided into three teams of four for the field assessment exercise and feed-back of results and adaptation options.

4.2.2 Summary of training intervention

Portions of three roads were assessed in order to cover as many of the assessment variables as possible. These were:

- Kukurantumi to Asoka: 7 to 8 year old paved road showing localised distress and unpaved experimental base section waiting to be surfaced – flat to rolling terrain.
- Anum Apapam to Obuoho: very low traffic, gravel road – hilly terrain.
- Akwesiho to Twenedurase: new gravel road being constructed – mountainous terrain.

Prior to departing for the Field Assessment exercise, a presentation discussing the objectives and techniques to be followed was presented at the KTC to all of the delegates.

Despite the current status and condition of the roads, successful demonstration of the assessment technique and manual was possible with almost all of the facility/attributes described in the manual being present at some point along the roads. This allowed significant discussion of the rating system and the attributes with the trainees. The only issues that could not be properly demonstrated in the field were potential subgrade problems and instability of fills, despite some high embankments being inspected. The assessment results are presented in Annex 2. Some of the photographs that were taken to illustrate certain defects are provided in Figure 3.

Figure 3 Some defects observed on the inspected roads

 Poor condition at start of Kukurantumi road – drainage problems	 Road failure due to poor subgrade beneath embankment
 Poor condition of Anum Apapam to Obuoho road – oversize material, drainage, erosion, weak subgrade	 Anum Apapam to Obuoho road – large culvert in structurally good condition but overtops periodically – needs cleaning – no head-wall

	
Seepage of water through gravel road from below – rocky subgrade in cutting	Slope instability problems due to overblasting

4.2.3 Observations

Kukurantumi to Asoka road:

The start of the road was in very poor condition due to ineffective side-drains. Although lined (concrete), they were blocked in places, ineffectively sloped and there was nowhere for the water to flow out of them.

Solution: Clean all drains in the area - survey their inverts to check flow capability and directions – install new cross-drain where appropriate.

Km 0.600 – severe deformation of the road surface (rutting, cracking, potholes, etc.) and loss of surfacing. Attributed to weak/soaked subgrade beneath 4 or 5 m of embankment. The GoogleEarth photo below shows evidence of an historic stream flowing in this area (under the Placemark) but would need to be proved by test pits at the base of the embankment.

Solution: Remove base and subbase over 30 to 40 m failed section, compact to as high a density as possible and reinforce top of embankment with geosynthetic and reconstruct pavement.

The road failures observed at km 0.9 were due to a local resident constructing a ramp over the side-drain by filling it in. Water was then forced into the adjacent pavement leading to extensive failures in this area.

Solution: Clean out drain and place concrete slabs over it to allow access to property.

No significant problems on the relatively recently new unpaved section other than road shape and localised erosion and drainage problems. These will be solved by planned reworking and paving of this section.

Anum Apapam to Obuoho road:

The initial part of the road in a "peri-urban" environment is paved with no major problems other than inefficient side-drains. However, the remaining unpaved section of the road had various problems along its length, the main problems being erosion and drainage, primarily related to the lack of maintenance. The poor finish of the road (and probably lack of maintenance) resulted in a poor road shape and consequently ineffective surface drainage. Local materials were erodible in places.

Solution: The road should be ripped and recompacted with a similar material, although the large quantities of oversize material should be removed. These interfere with the grader maintenance finish when this is carried out. Improved side-drains with the addition of mitre drains and some cross-drains are necessary. Precipitation accumulates on both sides of the road but can be removed to lower ground on the opposite sides where necessary.

The evident lack of maintenance has resulted in thick vegetation growth alongside the road; in some areas being so impenetrable that the condition of culverts in these areas could not be inspected.

Solution: Cut grass and remove thick bushes.

Akwesiho to Twenedurase road:

This road was under construction, having recently been regravelled at the time of the inspection. It was thus difficult to assess all of the road characteristics. Side drains were still being constructed, but erosion was visible in some of these.

The main reason for assessing this road was the presence of very steep grades and some relatively deep cuttings. Moisture in some areas was flowing on top of the rock subgrade beneath the wearing course.

Solutions: Sections of the side drains require lining and some mitre-drains or cross-drains to remove the water currently flowing into the subgrade. In some areas deeper side-drains are necessary to cut the water off.

A number of cuttings over a 200 m section are likely to prove unstable with localised rockfalls due to over-blasting and poor ripping management. Water was flowing through joints in some areas.

Solutions: Shape upper cut slope and construct catch-water and cut-off drains where necessary. Bar down over-blasted material to provide a smooth surface. Where necessary gunite (shotcrete) to bed loose materials and avoid undercutting and collapse of other materials.

4.2.4 Class-room debriefing

After a brief introductory presentation, the completed assessment forms were presented to the delegates and discussion as to identification of problem areas and possible adaptation solutions were discussed. It is interesting to see that the delegates and the presenter had very similar solutions to the problems.

These included:

- The use of geosynthetics over the weak subgrade areas
- The use of shotcrete on slopes on the Akwesiho – Twenedurase road that had some loose material
- The need to bar down and remove all separate material blocks where over-blasting has occurred.

Dominant problems seen:

- Lack of mitre drains and cross drains to remove water from alongside road at adequate intervals
- Moisture in subgrades due to different problems
- Inadequate maintenance

One issue raised by some of the delegates was that all roads (paved and unpaved) as well as bridges and culverts are regularly assessed in great detail every year for their respective Management Systems and this assessment was probably a duplication of this work. While it is admitted that the existing assessments will be invaluable for providing additional information and detail to the vulnerability assessments, different issues are assessed from a different perspective (i.e. longer-term effects). During the vulnerability assessments, the situation should be looked at in terms of expected changes based on the current visual evidence, unlike the current assessment process that monitors the existing condition.

At the end of the debriefing session, a short questionnaire regarding the course was handed out. Unfortunately, and despite a number of recent reminders, only four responses have been received so far. These are summarised in Annex 2.

4.2.5 Conclusion:

It was clear from the discussions with the trainees that some issues on the *Visual Assessment Manual* and associated assessment forms required expansion and clarification and some modification. Basic assumptions during preparation of the documents were not always clear to young and often inexperienced engineers. These have required clarification. The Manual has been updated taking cognisance of the above. In addition, discussions regarding quantification of the vulnerability index indicated that the assessment forms should have separate input areas for degree and extent to simplify the calculation of the vulnerability indices (cf. Section 5.2 and Annex 3).

Feedback from the few questionnaires returned indicated that, in general, the training exercise was valuable and well-received.

5 Activity Progress: Capacity Enhancement in Three Countries (Part B)

5.1 Updating of Handbook and Guidelines

As reported in previous Progress Reports, the Project Team developed a Climate Adaptation Handbook supported by the following three guidelines and manual:

- Change Management Guidelines
- Climate Threats and Vulnerability Assessment Guidelines
- Engineering Adaptation Guidelines
- Visual Assessment Manual

The above documents were reviewed extensively and their contents updated in line with feedback received from ReCAP PMU and from training and embedment workshops held in the three AfCAP Lead Countries. The revision of the above documents were undertaken between September and November 2018. The November 2018 versions of the documents have since been uploaded to the ReCAP website as 'Draft Guidelines for Comments (until 31 March 2019)', after which date the comments received will be assessed and, where justified, integrated in the documents so as to produce a final set of documents by 30 April 2019. At the same time the Project Team is also expecting feedback from peer reviewers appointed by ReCAP (e.g. the African Development Bank), which feedback will also be incorporated in the finalisation of the documents.

The following major changes were made to the above documents:

- Climate Adaptation Handbook:
    - Critical review of Part A ("Situational review and adaptation management") to align its content with that of the updated Change Management Guidelines
    - Updating of Part B ("Methodology") based on outcomes of field validation processes; greater focus on asset management, as well as on 'inadequate budget' strategies and local-level vulnerability assessments
- Change Management Guidelines:
    - Incorporation of feedback received from the non-engineering adaptation workshops held in the three AfCAP Lead Countries
    - Reformatting and reorganisation of guideline, including a review of actions that could be undertaken in the case of budget constraints/deficits
- Climate Threats and Vulnerability Assessment Guidelines
    - Redesign of the local-level vulnerability assessment methodologies
    - Integration of asset management in guideline document
    - Harmonisation of field assessment forms and consolidation into a single form
- Engineering Adaptation Guidelines
    - Enhancement of several engineering adaptation options by the integration of field verification and validation outcomes
- Visual Assessment Manual
    - Finalisation of the Manual and associated visual assessment forms, taking into consideration the recommendations of the Ghanaian training/embedment training (cf. Section 4.2)

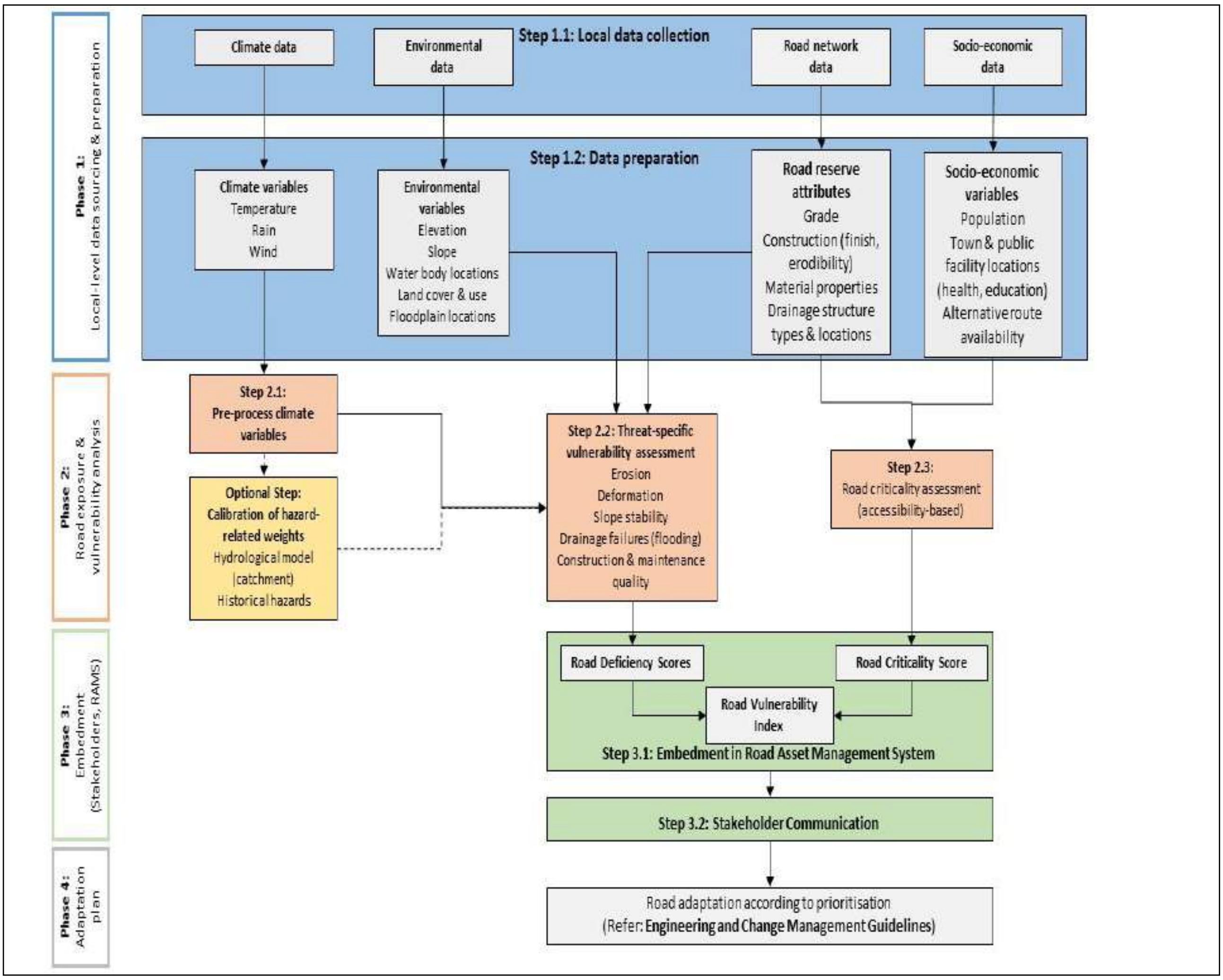
The November 2018 versions of the five documents are in the process of being translated in Portuguese. It is expected that the translation of the first three documents (*Climate Adaptation Handbook, Change Management Guidelines and Climate Threats and Vulnerability Assessment Guidelines*) will be completed by 1 March 2019. Arrangements have been made with the Mozambican Administração Nacional de Estradas (ANE) to assess the quality of the translations.

5.2 Quantified Vulnerability Index

At the ReCAP meeting held at the Durban Convention Centre (South Africa) on 10 October 2018, which focussed on the AfCAP Regional Projects dealing with Asset Management and Climate Adaptation, the ReCAP PMU identified the need for developing a quantified 'Vulnerability Index', bringing together the various components associated with vulnerability assessment as formulated in the *Climate Threats and Vulnerability Assessment Guidelines* and the *Visual Assessment Manual*.

The progress made by the Project Team towards the development of such a quantified "Vulnerably index" is presented in Annex 3. This work entailed the interrogation and redrafting of Steps 2.2, 2.3 and 3.1 of the local-level road vulnerability assessment framework shown in Figure 4.

Figure 4 Revised conceptual framework for the local-level vulnerability assessment of rural access roads



6 Activity Progress: Capacity Enhancement in Other Countries (Part C)

6.1 Dissemination at Conferences

6.1.1 Latest papers presented at conferences

The peer-reviewed paper titled “Implementing a GIS Based Methodology for Determining Highly Vulnerable Rural Access Roads to a Changing Climate in Ethiopia” authored by K Arnold, A le Roux and S Khuluse-Makhanya has been presented at the AfricaGEO 2018 Conference held at the Emperors’ Palace, South Africa, between 17 and 19 September 2018.

The peer-reviewed paper titled “Making Africa’s Roads More Resilient to Climate Change” authored by Dr P Paige-Green and B Verhaeghe has been presented at the SARF/IRF/PIARC Conference held at the Durban Convention Centre (South Africa) in October 2018. The paper was presented under the theme “Preserving Africa’s Road Assets”.

6.1.2 TRB Low-Volume Roads Conference

An extended abstract was submitted for a Special Low Volume Road (LVR) session/workshop at the 12th Transportation Research Board (TRB) LVR Conference that will be held in Montana, USA, between 15 and 18 September 2019. The title of the extended abstract is “Lessons learned and recommendations from embedding Climate Change Adaptation into the roads sector - from policy to practice” (authors: A le Roux, J Maritz, K Arnold, B Verhaeghe, M Roux).

The Project Team also provided assistance to ANE with the preparation of another extended abstract titled “Making rural access roads more resilient - Lessons learned from trailing the climate change adaptation handbook in Mozambique” (author: R Langa, assisted by A le Roux and P Paige-Green)

6.1.3 CAPSA Conference

A paper titled “The prioritisation and adaptation for climate change resilience of rural access roads” has been submitted to the organisers of the Conference on Asphalt Pavements for Southern Africa (CAPSA). The conference will be held between 13 and 16 October 2019 at Sun City, South Africa. The abstract reads as follows:

It has been estimated that by the end of the century, $150 billion will be required to repair and maintain existing roads in Africa, the majority of which will be low volume rural access roads. Research into the prioritisation and adaptation of roads to improve their climate resilience has shown that it is essential to provide good vulnerability assessment information to allow unbiased and equitable prioritisation for the installation of adaptation measures. Such measures will depend on the expected modes of climate change (higher or lower precipitation, higher or lower temperatures, etc.) as well as the nature, topography and materials along the road alignment. Most adaptation techniques will rely on exiting good engineering principles, although innovative solutions directly applicable to each situation will be necessary for low volume roads to ensure economic feasibility.

6.1.4 PIARC Conference

Three abstracts submitted for the 26th World Road Congress to be held in Abu Dhabi between 6 and 10 October 2019 have been accepted. Their titles, authors and abstracts are as follows:

Climate change adaptation in the African roads sector: Constraints, opportunities and policy challenges (authors: J Maritz, K Arnold, M Roux, A le Roux, B Verhaeghe)

Roads play a vital role in strengthening the socio-economic development of regions such as sub-Saharan Africa by providing local communities with critical connections between essential market points, service towns and infrastructure. The United Nations Environmental Programme describes the continent as a ‘vulnerability hotspot’ for climate change. During the past four decades African countries have experienced more than 1 400 recorded weather-related disasters. These disasters impact on affected countries’ *economies and, in particular, on rural communities and their livelihoods. Changes to the region's climate are causing widespread damage to road infrastructure and its associated assets. Rural accessibility is being compromised by climate variability in a number of countries for periods of the year, creating both direct and indirect adverse effects on livelihoods and associated socio-economic development. Although many countries in the region have undertaken climate commitments, policy has not always been translated into actions in all sectors; the transport sector (especially rural roads) has not featured strongly when countries consider climate change actions. To enhance the capacity of roads authorities to reduce the current and future impacts of climate change, a project was initiated by the Africa Community Access Partnership (AFCAP), a research programme funded by UK Aid, to focus on climate adaptation. Through research and knowledge sharing the objective was to compile pragmatic, cost-beneficial engineering and non-engineering procedures that could be used to guide roads sector institutions to address climate threats. Through the project, a methodology for carrying out climate adaptation assessments for rural roads which was developed and packaged into a handbook and series of linked guideline documents. The project further looked at addressing capacity enhancement in the AfCAP partner countries to ensure that there is a strong focus on embedment and uptake. The study focused predominantly on three countries, namely Mozambique, Ethiopia and Ghana. In order to embed climate change adaptation into the respective national transport authorities, several constraints had to be addressed. Two prominent issues emerged; the first being the lack of in-country collaboration between sectors when dealing with climate change science, and the second being policy gaps that address climate change in the transport sector. These constraints have affected the capacity of the national transport authorities in the various countries to incorporate climate change risk and vulnerability into their planning systems. The project therefore provided an opportunity to address these challenges and to enable the practical implementation of Climate Change Adaptation into the roads sector.*

The development of a rural road vulnerability assessment framework to inform the local climate change adaptation strategy and implementation (authors: S Khuluse-Makanya, A le Roux, K Arnold, P Paige-Green, B Verhaeghe)

Climate change adaptation of road infrastructure is a complex process given the variability in temporal and spatial scales of elements that need to be considered and the challenge of having to balance the diverse goals of stakeholders with differing mandates and capacities. As part of the adaptation pathway, the risk and vulnerability of assets of varying life spans need to be considered against environmental change (climate and land cover change) and socioeconomic change which include population dynamics (growth, decline and spatial distribution), technology shifts and changes in governance which have an effect on the success of local implementation of adaptation options.

A circular approach was undertaken in developing a framework for local-level vulnerability assessment of rural access roads to climate-induced environmental hazards and long-term climate change. This was for a project by the UK Aid funded Africa Community Access Partnership (AFCAP) research programme which focuses on climate adaptation. The framework was developed to enhance the user's understanding of climate hazards that need to be considered for rural road networks and how those hazards translate into increasing vulnerability for the road network, the dependent population and the economy. The framework includes identifying road segments that are vulnerable to specific climate hazards, the assessment of the likelihood of such hazards intensifying or diminishing in the mid- to long-term future. The circularity of the approach is demonstrated by the sequential process of developing the framework and a data collection tool that emphasized physical road attributes and environmental vulnerability factors, engaging stakeholders on the sensibility of the framework and practicality of the data collection process, and then the revision of both the framework and the tool. The latter consisted of incorporating data entry prompts for environmental vulnerability factors into a routine road assessment survey used for collecting data that are stored in road asset management systems for use in engineering design and maintenance. The findings from the pilot study were that the framework is useful as a guide for the management of road and related environmental data. Further, the appraisal of risk and vulnerability helps road engineers in prioritising and implementing adaptation options as well as inform other stakeholders involved in infrastructure-related climate change adaptation planning.

Embedment of climatic effects in the road asset management process (authors: M Roux, P Paige-Green, B Verhaeghe, J Maritz, K Arnold)

The United Nations Environmental Programme describes the African continent as a 'vulnerability hotspot' for climate change. During the past four decades African countries have experienced more than 1 400 recorded weather-related disasters. Changes to the region's climate are causing widespread damage to road infrastructure and its associated assets. In order to help address this significant threat to Africa's development, the Africa Community Access Partnership (AfCAP), a research programme funded by UKAid, has commissioned a project, starting 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.

As part of this study, a two-stage process for the embedment of climatic effects in the road asset management process has been developed. During the first stage, the outcomes of district-level climate change risk and vulnerability assessments were embedded in the road asset management process, with the aim to firstly identify the most vulnerable districts under current climate and socio-economic conditions and, secondly, to identify future vulnerable districts under a changing climate and growing population. During the second stage, specific climate effects on road infrastructure in these vulnerable districts are to be recorded, measured and rated. Problems specifically related to climatic effects are to be identified and described by way of a visual assessment process. During the visual assessment process, predefined climatic effects are rated using a likelihood/consequence estimate of the risk. Each climate effect is rated on a scale from 1 to 5 in terms of its likelihood and its impact. The risk associated with the specific aspect is then calculated as the product of the likelihood and impact ratings. The likelihood and impact ratings of the various climate effects are then used to calculate a Climatic Effect Risk index (CERI). The relative importance of the climatic effects is taken into account in the calculations by assigning different weights to the different effects. The CERI can then be used to rank specific roads in terms of priority for adaptation to make vulnerable roads more climate resilient. The above approach, which has been tested in Ethiopia, Ghana and Mozambique, complements the more traditional road asset management systems by adding another layer that will support prioritisation of investments in road assets and decision support.

6.1.5 T2 Conference

The Project Team assisted ANE in the preparation of an abstract and paper for the 9th Africa Transportation Technology Transfer Conference that will be held between 24 and 26 July 2019 in Maputo, Mozambique. The paper is titled "Making rural access roads more resilient - Lessons learned from trailing the climate change adaptation handbook in Mozambique" (author: R Langa, assisted by J Komba and P Paige-Green).

6.2 Publication of the Handbook and Guidelines on the ReCAP Website

Changes are being made on a continuous basis to the Climate Adaptation Handbook, the three associated Guidelines and the Visual Assessment Manual.

It was noted in the 5th Progress Report that these documents had to be published as soon as possible on the ReCAP Website, enabling practitioners in other sub-Saharan countries as well as allowing interested parties from other regions/continents to access the documents, comment on them and/or start implementing relevant parts of these documents. These documents could also already be used for academic or other purposes.

These documents are now available on and can be downloaded from the ReCAP website. They are all labelled as "Draft for Comments" with the deadline for submitting comments set for 31 March 2019. In April these documents will be finalised and made available to the international community as 'best practice' documents to support the public and private sector, NGOs, academia and others with the expectation that they will be implemented and incorporated in decision-making processes and operations, and/or will be used for dissemination and training purposes.

6.3 Training-of-Trainers Programme

The Training-of-trainers programme has been initiated and letters of invitation to the AfCAP Lead Countries to act as hosts, and when confirmed, to the AfCAP participating countries linked to each one of the host countries have been issued or are in the process to do so. An example of an invitation letter (for Sierra Leone) is provided in Annex 4 as an example.

The Train-the-trainer programme needs a specific approach to ensure optimum response for proper embedment. It might require two stages of which Stage 1 is provided for in Phase 2 of this project:

Stage 1:

Initially, a group of three potential trainers from each country should be identified for the preliminary/ introductory course (i.e. purpose of this training intervention). The training approach is for the Project Team to instil in the Trainee Trainers (TT) a sense of independence in equipping themselves to become fully-fledged trainers in climate adaptation. This entails providing the TTs with a comprehensive list of background/supporting material and outlines of presentations for various aspects of the topic. This information should be sufficient for each TT to obtain appropriate information so that they can prepare their own country-customised PowerPoint presentations on particular issues within the overall topic (Climate Change assessment and adaptation in this case). This work must be supported by adequate field visits to ensure that the TTs understand all of the field vulnerability assessment issues comprehensively. This will take some time to cover the wide range of issues necessary for routine assessments. Guidance must also be provided to the TTs on how to prepare well-structured PowerPoint slides and to deliver effective presentations.

On the last day of the five-day course, each of the TTs (they probably will have to be grouped by country) will be requested to present a self-prepared aspect of the course to the rest of the Training team under the supervision of the Project Team, with discussion and comments to ensure that all issues are clearly understood. Thereafter, the TTs should be in a position to hone their newly acquired skills by making further presentations to new trainees.

The TTs will be examined on the theoretical and practical issues covered and their specific intentions of becoming trainers. Some of the delegates trained may have been incorrectly identified by their superiors and have no desire or intention of becoming trainers.

Stage 2:

The next stage would involve the delivery of the full course by the TTs to groups of new trainees (8-10) under the guidance of the Project Team. At the end of the course, a proficiency assessment of the Trainee Trainers and the new trainees is carried out to determine the effectiveness of the Trainers and the degree of comprehension of the new trainees. This would have to take place during Phase 3 of the Project.

The current status of the agreed dates and responses received for Stage 1 is presented in the Table below.

Table 2 Status of AfCAP partner country participation in Training-of-Trainers Programme

Host Country, Status, Date and Delegates	Associated Countries, Status and Delegates
Mozambique Status: confirmed Date: Week of 25 March 2019 (5 days) *Proposed delegates:* 1) Raquel Langa, ANE 2) Fernando Dabo, ANE 3) Moises Dzimba, ANE 4) Eng Carlos Cumbane, LEM	**Malawi** Status: Expressed willingness to send delegates Proposed delegates: Unknown
	Tanzania Status: Confirmed Proposed delegates: 1) Eng. Vincent Lwanda - TARURA 2) Eng. Ezron Kilamuhama - PO RALG HQ 3) Qs Tenga - TARURA

Host Country, Status, Date and Delegates	Associated Countries, Status and Delegates
	Zambia Status: Confirmed Proposed delegates: 1) Joseph Chibwe (Principal Engineer Highway Management System) 2) Phillimon Goma (Principal Engineer - Technology and Processes) - Research 3) Victor Miti (Engineer HMS)
Ghana Status: confirmed Date: Week of 1 April 2019 (5 days) Proposed delegates: to be confirmed	**Democratic Republic of Congo** Status: Expressed willingness to send delegates Proposed delegates: Unknown
	Liberia Status: Unknown Proposed delegates: Unknown
	Sierra Leone Status: Expressed willingness to send delegates Proposed delegates: Unknown
Ethiopia Status: to be confirmed Date: Week of 13 May 2019 (tentative) Proposed delegates: Unknown	**Kenya** Status: To be invited Proposed delegates: Unknown
	South Sudan Status: To be invited Proposed delegates: Unknown
	Uganda Status: To be invited Proposed delegates: Unknown

7 Activity Progress: Embedment (Part D)

7.1 General

Part D of the project focusses on uptake and subsequent embedment of outcomes aimed at a range of levels from informing national policies, through regional and district planning, down to practical guidance on delivery at rural road level.

Whilst the latter has been addressed in preceding Parts of the project (A to C), particularly focussing on the engineering level (i.e. identification of vulnerabilities and adaptation solutions, supported by the Climate Adaptation Handbook, the three associated Guidelines and the Visual Assessment Manual), the former focusses on policies, strategies and plans, and the embedment of climate change into those with a particular focus on protecting and sustaining rural accessibility.

A series of workshops and subsequent meetings have been held in the three Lead Countries (Ethiopia, Ghana and Mozambique) with the aim to:

1. Identify and agree on areas and actions for the Project Team to assist the three Lead Countries with the embedment of climate resilience in policies, strategies and plans;
2. Explore the integration of climate adaptation considerations in asset management; and
3. Explore the embedment of the vulnerability assessment methodology in decision support systems, including Geographic Information Systems (GIS), and to demonstrate how it can be applied to support high-level decision making.

The Project Team's members involved in these workshops and meetings were Mr Johan Maritz (policy), Ms Kathryn Arnold (country-level vulnerability assessments) and Mr Michael Roux (asset management).

The outcomes of the workshops and meetings held in Ethiopia, Ghana and Mozambique were reported in the 4th and 5th Quarterly Progress Report.

7.2 GEM PIT Meeting held in Zambia

The AfCAP Regional Project on Economic **G**rowth through **E**ffective Road Asset **M**anagement (GEM) held a Project Implementation Team (PIT) meeting in Lusaka, Zambia, on 20 and 21 November 2018. Two members of the Project Team (P Paige-Green and M Roux) were requested to participate and lead a two-hour mini-workshop on Climate Resilience in Road Asset Management on the second day of the PIT meeting.

The purpose of the climate change mini-workshop was to discuss how recommendations from the climate adaption study could be built into rural road asset management at a local authority or road agency level in Africa. The mini-workshop focussed on matters such as what type of assessments are feasible at the local level, how often must they be carried out and what skills and training are required to carry out these local level assessments.

The participants included district road engineers from districts in Sierra Leone, Uganda, Zambia and Tanzania as well as engineers from national road authorities and research units in these countries. The total number of participants was about 40, including the GEM team.

Mr Roux did a presentation on embedding climate change effects in Road Asset Management. The presentation covered aspects such as a brief overview of Road Asset Management; embedding climate change effects in road asset management during the various steps in the Asset Management process; embedment of district-level climate risk and vulnerability assessment in RAMS; and embedment of local-level climate risk and vulnerability assessment in RAMS.

Dr P Paige-Green presented on the visual assessment process at road link level obtain the required inputs for climate resilience assessments and the implementation of appropriate adaptation techniques to improve the climate resilience of the infrastructure. The presentation covered the process on how to do these visual assessments; what issues to assess; how the distresses related to climate change effects are rated in terms of degree and extent; and skills requirements for doing these assessments.

Following the presentations, a discussion was held during which issues raised and questions posted were answered by Dr P Paige-Green and M Roux. Overall, the processes and method presented on how to embed climate change effects in road asset management were well received by the delegates at the PIT meeting.

7.3 Country reports

Final drafts of the Country Reports for Ethiopia, Ghana and Mozambique were submitted to ReCAP PMU in December 2018. These reports incorporated a number of changes based on comments received from the ReCAP PMU. These included:

- Harmonisation of the structure of the three reports.
- Tightening up of the reports so that they are more country focussed (i.e. replacement of generic information in the reports with references to the Climate Adaptation Handbook and associated Guidelines).
- Removal of repetition of general data about the countries.
- Clearer definition of the reports' objectives.
- Updated information on policies and on how these are being delivered through standards and specifications, particularly in the reports on Ethiopia and Mozambique.
- Inclusion of sources of data for each country.
- Inclusion of more clearly marked subheadings in the figures showing the downscaled climate.
- More emphasis put on the increased vulnerability of rural roads to climate-degradation if they are poorly designed and maintained.
- Clearly noted that the Rural Access Index (RAI) used in the Mozambican report is not the standard RAI (it uses 5km as opposed to 2km).
- Clearer definition of what is meant by 'vulnerability' in reports.
- Better explanation of the state of readiness of the asset management system in each country to take on board climate impact issues.
- Inclusion of relevant aspects of the AfCAP report AFCAP/GEN/127 by Gareth Hearn on climate in sub-Saharan Africa.
- Update on how policies are being translated into practice and how improvements could be made.
- Greater emphasis placed on cross-sector/cross ministerial cooperation.

Subsequently, the Country Reports were sent to ERA (Ethiopia), DFR (Ghana) and ANE (Mozambique) for final review. Additional changes made to the reports are as follows:

Ethiopia:

- (to be added)

Ghana:

- (to be added)

Mozambique:

- Updating of information on road conditions
- Inclusion of additional sources of local data/information in the tables.

8 Activity Progress: Recommendations for Phase 3 (Part E)

Preliminary recommendations for Phase 3, as well as a preliminary budget, were submitted to ReCAP in December 2018. Being preliminary at this stage they will undergo further enhancements based on discussions that will be held with ReCAP PMU. Final recommendations will be proposed in the Closure Report for Phase 2.

The following Work Packages (WPs) were proposed for Phase 3:

8.1 WP 1: Situational analyses, mapping of vulnerability to climate change, policy implications, embedment of Stages 1 and 2 of Climate Adaptation Methodology, and Country Reports

WP 1 will consist of three main tasks with the objective of Informing/supporting policy changes in each ReCAP Partner Country by mapping risks and vulnerabilities within the context of rural accessibility and also to streamline policy work in conjunction with other initiatives (e.g. SDG 11 –RAI).

Task 1.1: Pre-workshop preparation

Three Sub-tasks will be undertaken, resulting in comprehensive supporting information to conduct training workshops and facilitate the country report generation.

Outputs will include: (1) Climate Change projections, risk and vulnerability assessments and policy environment scoping; (2) identified country stakeholders and workshop delegates to provide inputs into preliminary findings and provide supporting information/and or missing info; and (3) identified delegates that will receive training on the guidelines and handbook and for the co-development of country reports.

With assistance provided by the Countries Counterparts, relevant country stakeholders as well as workshop delegates will be identified, nominated and secured for three purposes: (1) introductory meeting with key Ministry, Department and Authority/Agency (MDA) stakeholders; (2) providing inputs into the country-specific findings presented by the project team (i.e. first-level Country Reports); and (3) training on Stages 1 and 2 of the climate adaptation methodology (i.e. on relevant aspects of the *Climate Adaptation Handbook,* as well as on the *Change Management Guidelines* and the *Climate Threats and Vulnerability Assessment Guidelines*).

The sub-tasks to be undertaken in South Africa on the basis of a staged approach over the duration of the contract period are as follows:

Sub-Task 1.1.1: *Comprehensive overview of policy environment*

- Confirmation of Country Counterparts for the purpose of Phase 3 of the Climate Adaptation project.
- The policy environment of all AfCAP and AsCAP countries will be examined and assessed. The team will consult all relevant government and MDA's policies and plans related to climate change adaption in the roads sector. The team will consult the relevant development partners prior to the workshop to ensure a comprehensive overview of the space. The purpose is to identify the right stakeholders and change management processes/partners that need to be involved in the workshops. The process will also facilitate the streamlining of data sources for the risk and vulnerability assessments and highlight data and capacity constraints.

The outputs will include:

- Policy environment overview with change management scope
- Supporting information for the change management guideline training
- Identified workshop participants to facilitate change management

Sub-Task 1.1.2: *High resolution climate projections with extended variables*

For all AfCAP and AsCAP countries high resolution projected climate data will be produced for a RCP8.5 (Worst case scenario) mid-century and end-century future. It is also suggested to extent the current set of variables to include evapotranspiration, a drought index, heat-wave days and high fire danger days (as proposed in the guidelines) to cater for the needs in both the risk and vulnerability assessment as well as the local engineering adaptation assessments.

The team will engage the relevant meteorological offices and relevant academic institutions before modelling to ensure duplication is minimised and to use in-country data where possible.

The outputs will include:

- Datasets to be used in the risk and vulnerability assessments and engineering adaptation assessments
- Descriptive information on the current climate as well as potential shifts in future climate for all countries involved.
- The datasets will also be packaged into the data distribution package as part of the country reports.

Sub-Task 1.1.3: *Conducting Risk and vulnerability assessments*

Using the developed ReCAP assessment methodology, risk and vulnerability assessments will be conducted for all participating countries using the current and projected climate data as well as sourcing relevant data from all identified stakeholders. The team will liaise with all identified parties (identified as part of Sub-Task 1.1.1) to ensure effective data sourcing and to minimise data duplication.

Outputs include:

- District risk and vulnerability assessments
- Supporting information for the risk and vulnerability assessment training
- Relevant data sources packaged to form part of the Country Reports

Task 1.2: Workshop (roll-out training/knowledge transfer of handbook & guidelines)

The purpose will be to visit the countries for the purpose of training and capacity development of predefined individuals to facilitate change management.

The objectives are:

- Training and capacity development
- Testing preliminary findings (policy environment and risk and vulnerability assessments)
- Identifying co-developer champions for the collaborative country reports

Proposed activities to be undertaken in each of the ReCAP Partner Countries on the basis of a staged approach over the duration of the contract period (one week per country) are as follows:

- *Day 1:* Country Inception Meeting with MDA key stakeholders to introduce climate change adaptation, the handbook and guidelines, and presenting/confirming objectives and in-country activities (and to secure buy-in from key stakeholders)
- *Day 2:* Workshop with identified champions (who will co-develop country reports) to deliberate on country-specific findings (i.e. status of policies et al, and climate vulnerability) as presented by the project team; and to verify and test data and supplement with information
- *Day 3:* Meetings with other stakeholders (e.g. development partners) to verify and test data and supplement information
- *Day 4:* Training on the risk and vulnerability assessment guidelines
- *Day 5:* Training on change management guidelines, and meeting with MDA key stakeholders to provide feedback on the week's activities and outcomes.

During that week, actions to support the activities of Work Package 2 will also be undertaken. This will include the identification of potential low-volume rural roads that could to be used for training on Stages 3 to 5 of the climate adaptation methodology.

The outputs will include a record of the outcomes of the meetings and workshops held, which will be integrated in Quarterly Progress Reports.

Task 1.3: Co-production support for country report development

The pre-workshop support information (data and reports) as well as all recommendations received from the workshop will form the base of the Country Reports.

The nominated workshop participants will apply the guidelines and handbook in order to co-produce (with support of the Project Team) a country assessment report with clear change management recommendations.

The outputs with be co-produced Country Reports, one for each of the ReCAP Partner Countries.

8.2 WP 2: Provision of training on Stages 3 to 5 of Climate Adaptation Methodology

Task 2.1: the following activities are proposed to be undertaken in South Africa on the basis of a stage approach over the duration of the contract period:

- Confirmation of a suitable low-volume rural road in each of the ReCAP Partner Countries that is at a (pre-)planning stage and can be used as a test case for training purposes on Stages 3 to 5 of the climate adaptation methodology (based on outputs of Tasks 1.1 and 1.2).
- Gathering and processing of appropriate information on selected road section and preparation of presentation and handout material (for all countries).
- Through the Country Counterpart, identify, nominate and secure representative country workshop participants for hands-on training on Stages 3 to 5 of the climate adaptation methodology (for all countries).

Task 2.2: Proposed activities to be undertaken in each of the ReCAP Partner Countries on the basis of a staged approach over the duration of the contract period (one week per country) are as follows (Note: locally-acknowledged trainers would have to be involved in the sub-activities below for the purpose of capacitating other practitioners nationally):

- *Two-day introductory workshop* on the Climate Adaptation Handbook (with particular focus on Stages 3 to 5 of the climate adaptation methodology), the Engineering Adaptation Guidelines and the Visual Assessment Manual.
- *Three-day, hands-on training* on the in-field identification of potential environmental-associated threats on the functionality of the test case road, identification of remedial options to render the road climate resilient and the optimisation/prioritisation thereof.

Task 2.3: Contribution to the Quarterly Progress and Final Report (i.e. summary reports on workshops and in-field training, and lessons learnt).

8.3 WP 3: Assessment of uptake and embedment in AfCAP Lead Countries for Phases 1 & 2

Task 3.1: The three AfCAP Lead Countries that formed the core focus of activities undertaken in Phases 1 and 2 of the AfCAP Climate Adaptation project, namely Ethiopia, Ghana and Mozambique, will be revisited to monitor/assess the level of embedment of climate adaptation processes in their practises and policies.

Task 3.2: The demonstration sections constructed in the Gaza Province of Mozambique will be visited at least twice during the execution of Phase 3, typically after the wet season, to monitor the performance of the sections. A report will be produced after each visit which will be incorporated in the Quarterly Progress Reports. A stand-alone report on the design, construction and performance of the demonstration sections will also be produced.

8.4 WP 4: Dissemination and Reporting

Task 4.1: Development of Inception Report for Phase 3 based on the following:

- Seminar that will be held within one month from the activation of Phase 3 and involving all ReCAP countries; at which event the objectives, activities, timelines and planned outcomes of Phase 3 will be presented and debated
- Reformulation and re-programming of activities to be undertaking in Phase 3 to secure alignment with needs expressed by individual ReCAP Partner Countries, and acceptance thereof by ReCAP.
- Drafting and finalisation of Inception Report.

Task 4.2: Preparation of Quarterly Reports satisfying the contractual Milestone requirements as agreed with ReCAP PMU (subject to changes as per the outcomes of Activity 4.1).

Task 4.3: Updating of the Climate Adaptation Handbook, Guidelines and Manual

Improvements will be made to the Handbook, Guidelines and Manual, and additional non-engineering and engineering adaptation approaches and solutions will be integrated in the documents based on feedback received from the WP1 and WP2 workshops held in the ReCAP countries so as to also reflect unique local conditions (sea level rise, wind-blown sand conditions, etc.).

Task 4.4: Preparation and presentation of at least three peer-reviewed conference papers and one published journal article.

Task 4.5: Inter-regional Seminar on climate adaptation to present and deliberate the outcomes of the Phase 3 of the project.

Task 4.6: Preparation of a Final Report for the Climate Adaptation project, also reflecting back on the processes followed, outcomes and achievements of Phases 1 and 2.

8.5 Deliverables

The following technical and contractual reports are envisaged:

- Inception Report for Phase 3
- Quarterly Progress Reports
- Workshop Summary Reports, which could be included as Annexures to the Quarterly Reports
- Fourteen individual Country Reports
- Report on the design, construction and performance of the Mozambican demonstration sections
- Pre-Final and Final Project Reports
- Peer-reviewed conference papers and journal article.

9 Preliminary Cost-Benefit Analysis

A preliminary cost-benefit analysis was conducted in December 2018 to quantify the return on investment for the AfCAP Climate Adaptation project. The assumption made, the methodology adopted and the results of the analysis are presented below.

9.1 Projected impact of climate change on sub-Saharan African road infrastructure

Chinowsky et al (2013) estimated that the African continent may be facing USD 183.6 billion liability to repair and maintain roads (within the current road inventory; thus excluding new roads) damaged from temperature and precipitation changes directly related to projected climate change through 2100. They estimated that, based on six climate scenarios, the proactive and reactive costs for dealing with climate impacts are estimated to range, respectively, from an average of USD 22 million to USD 54 million annually per country. The following were also noted:

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

The above point towards the need for particularly sub-Saharan African countries to reconsider policy and development plans to offset the effects of weather variability and climate change on road infrastructure.

The AfCAP Climate Adaptation project addresses a multitude of dimensions to create both awareness and action agendas to mitigate the impacts of climate change; from practical engineering adaptation solutions, through climate vulnerability assessments and adapted asset management practices, to instilling regulatory/policy changes at national levels. These are described below.

9.2 Project deliverables and their potential to act as Change Agents

9.2.1 Engineering guideline

The Engineering Guideline (and associated Visual Condition Assessment Manual) is of such a nature that it does not only address options for rectification of "weak links" on access roads that may be impacting by adverse/cataclysmic climate events, but it also instils a culture of "adapt", i.e. implementation of sound engineering decision-making processes that consider climate effects and their impacts (and awareness of the consequences of "no adapt"). The adoption of "good engineering practices" permeates throughout this

Guideline for the purpose of providing sustainable all-weather access, ranging from best practices for ‘adapted’ gravel roads to similar practices for surfaced roads, drainage and bridge structures, slope stability, maintenance and construction practices as well as others. The Guideline also addresses the benefits of the “adapt” approach vis-à-vis the “no adapt” option. Adaptation design can be based on the more traditional cost-benefit analyses, but also on meeting demands and not exceeding unacceptable risks at the lowest possible cost.

Of note is an extract from the AfDB report entitled “The cost of Adaptation to Climate Change in Africa” (AfDB, 2011) – incidentally the three countries described below are the three Lead Countries that AfCAP focussed on in their Climate Adaptation programme:

> *The World Bank (2010) study provides bottom-up evidence on adaptation needs in a number of countries including in **Mozambique**, **Ethiopia** and **Ghana**. Although such case studies cannot provide an overall picture of the costs of adaptation, the three countries represent nearly the full range of agricultural systems in Africa and hence provide a significant diversity of potential climate change impacts and adaptation responses. For each country, adaptation options are identified and costed for the key sectors, although the costs of private (autonomous) adaptation are excluded. As such, the true costs of adaptation are likely to be higher.*
>
> *– The country study for **Mozambique** estimates investment costs of around US$ 400 million per year over 40 years for the adaptation options identified. **One adaptation option – sealing unpaved roads, a ‘low regret option’ likely to yield significant benefits no matter the extent of climate change – would restore about one fifth of the welfare loss owing to climate change.** The remaining welfare losses could be regained with better agricultural productivity or through the improvement of education, each at a similar overall cost. Irrigation investments are found to be a poor adaptation option.*
>
> *– Adaptation costs in **Ethiopia** are estimated to be far higher, at US$ 1.22 billion in the wet climate scenario and US$ 5.84 billion in the dry scenario. These adaptation measures include increased use of irrigation, **paving roads**, improving hydropower projects and ‘soft’ adaptation measures such as changes in **transportation operation and maintenance and the development of new design standards**. Without adaptation, Ethiopia’s GDP in 2025 would be lower by 2 - 8% as a result of climate change. The adaptation measures studied can reduce this welfare loss by roughly 50%.*
>
> *– The report considers similar measures for **Ghana**, where it estimates that climate change will cause a reduction in real household consumption of 5 - 10% in 2050, with an economy wide reduction in real GDP of 1.9 - 7.2%. However, although the report discusses various adaptation measures at length, and analyses their strengths and weaknesses, it does not provide an overall cost estimate.*

Through the assistance of several Development Partners such as the World Bank, the EU, DFID, Nordic Aid and others, such challenges are currently being addressed, particularly in Ethiopia and Mozambique. However, the main focus of these interventions is to build (sustainable) infrastructure and not necessarily to develop local capacity to replicate the same. Most of the above initiatives are often led by foreign consultants (and involving an increasingly foreign contractors’ workforces) and thus do not provide the basis for local engineers and contractors to develop their own adaptive capabilities and capacity to handle the challenges themselves.

Although the upgrading of roads to appropriate standards is a common theme among all ReCAP programmes, one of the core objectives of this AfCAP project is to develop and to establish national capability among especially road engineers, through induction and awareness-creating workshops and train-the-trainers programmes, to build and embed climate-resilience in all projects to be undertaken in their respective countries.

9.2.2 Climate Threats and Vulnerability Assessment Guideline

Background: Rural road infrastructure is vital in supporting the delivery of essential utility services and has great strategic, political, economic and social significance. This infrastructure is designed to 'fit' into a local environment and to withstand a defined variety of forces that could destabilise the integrity of the infrastructure. Its design is generally based on classifications informed by up to five decades of historical climate data. With climate change, road design parameters based on historical climate data will be (and have already proven to be) inadequate, given that in this century the frequency and magnitude of extreme weather events is expected to increase. The effect of these changes could result in severe consequences to the existing rural road networks as well as on future road developments if the necessary mitigation (e.g. provision of adequate maintenance), adaptation (e.g. retrofitting) and precautionary actions are not timeously implemented.

The *Climate Threats and Vulnerability Assessment Guideline*'s purpose is to take the user through the process of getting to a comprehensive understanding of the biggest climate threats posed to the road network and how these threats translate to an increasing vulnerability of both the road network and the dependent population and economies. The Guideline focusses on how these approaches will differ given the scale of analyses conducted and the different role players, methods, tools and data needed to conduct such a threat and vulnerability study. The Guideline supports the user to create a series of profiles (maps and indicators) by utilising existing tools, methods and data in order to enhance the users understanding of current high risk areas in need of intervention. Utilising a series of forward looking socio-economic principles and climate change models will support the user in obtaining a better understanding of plausible shifts in future threats and vulnerabilities.

This Guideline is structured to, (a) guide a user through the steps involved in conducting a rapid risk and vulnerability assessment in their respective countries even though variations in the availability and quality of data are present, and (b) guide the user through a project level risk and vulnerability study when implementing new or maintaining/retrofitting existing infrastructure.

The national/district-level assessment is geared towards providing evidence to national or international stakeholders such as funders of government road asset investment projects, while the local assessment can accommodate a higher level of detail aimed at assisting road construction and engineering professionals to prioritise suitable interventions on specific road sections taking into account identified climate threats.

The above approaches have been piloted in three countries, namely Ethiopia, Ghana and Mozambique, and yielded wide-range acceptance for the implementation of these concepts in decision support systems, inclusive of their national road asset management systems which are now also expected to embed a climate dimension that will inform prioritisation of investments. In addition to the above, it has stimulated inter-Departmental dialogue and cooperation to instigate a more inter-Departmental approach to address community-based impacts of climate variability and impact.

9.2.3 Change Management Guideline

Change Management with respect to Climate Change has the potential for making significant strides towards creating resilience to climate effects in a cost-effective way. The *Change Management Guideline* covers policy and planning, stakeholder and asset management and involves the formulation of strategies and programmes for improvement. It also pays attention to the management of measures that could be taken when budgets are inadequate or absent for a "no adapt" option, sometimes referred to as the "do nothing" scenario.

While this Guideline is in large an Induction Guide, many of the aspects presented in this Guideline have been introduced to the three Lead Countries involved in this project (Ethiopia, Ghana and Mozambique), and after discussion with the leadership of those countries, appropriate elements are now in the process of becoming embedded in their operations, regulations and policies. Of note is that Country Reports have been drafted for the three Lead Countries, encapsulating resolutions made, based on the broad concepts outlined in the Change Management Guideline.

9.2.4 Climate Adaptation Handbook

The Climate Adaptation Handbook provides relevant information on climate adaptation procedures for rural road access, along with a methodology to address climate threats and asset vulnerability, and to increase resilience in a systematic manner. It has been developed to cover a wide range of climatic, geomorphologic and hydrological circumstances, based on application to Mozambique, Ghana and Ethiopia, but equally applicable to any sub-Saharan country.

While the Handbook is an overarching document and illustrates the fundamental principles, processes and steps required for climate resilience, it is supported by the three above-mentioned guidelines.

9.3 Cost-Benefit Analysis (CBA) for GEN2014C

Since the outputs of the project are largely intangible products, ranging from awareness creation, hands-on training, guidelines, manuals and country reports, as well as embedment activities associated with, for instance, decision support, and supporting policy changes, quantification of the project's tangible benefits is not a trivial exercise.

Using an analogy, approximately GBP 950,000 has been invested in Phases 1 and 2 of GEN2014C. Given that the medium cost for constructing a low-volume road is approximately GBP 100,000 per kilometre, the investment made in GEN2014C equates to approximately 9.5 kilometres of a low-volume road. The question that now needs to be asked is whether the (intangible) benefits accrued from this project, on the assumption that the project's outputs and outcomes have been (fully) embedded in at least three AfCAP partner countries, equate to a value of only 9.5 kilometres of road, given the extent (and condition) of the road networks in these three countries (Ethiopia: 110,400km; Ghana: 109,500km; Mozambique: 32,100km; **Total:** 252,000km). Even if the impact of the project would beneficiate only 1 percent of the above total road network by attaining improved all-weather performance and accessibility (and excluding all associated socio-economic benefits), the "return on investment" would be in the order of 265 percent.

The above is but one way to assess the potential cost-benefits. Another way could be to assess the "Adapt" and "No-Adapt" policy options, and calculating the potential length of new roads that could be constructed based on assumptions on the shift from the "No-Adapt" to the "Adapt" policy option.

10 Progress

10.1 Summary of Progress

As a result of several delays experienced by the Project Team, a contact amendment was requested in December 2018, which ReCAP PMU subsequently approved. The completion date was extended from December 2018 to May 2019.

The actual and planned completion dates for the Work Packages are shown in Table 3 below. Tasks and/or activities that have not been completed and are unlikely to be completed in Phase 2, are marked "**See Note 1**". These are discussed below the table.

New estimates for the completion dates of tasks that are still ongoing are shown in **blue**. The estimated completion dates are dependent on the level of cooperation that the Project Team will receive from the AfCAP Lead Countries, as well as from the other AfCAP Partner Countries.

Table 3 Actual/anticipated completion dates of Work Packages

WORK PACKAGE	COMPLETION DATE
Inception Phase	15 June 2017
Management & Recommendations for Phase 3	**31 May 2019**
A.1: Mozambique demonstration programme • *Detailed design* • *Construction* • *1st Monitoring & evaluation (demonstrations)* • *Demonstrations: vulnerability assessment & RAMS*	 September 2017 **March 2019** **April 2019** April 2018
A.2: Ghana demonstration programme • *Detailed design* • *Construction* • *Monitoring & evaluation (demonstrations)* • *Demo vulnerability assessment & RAMS*	 February 2018 **See Note 1** **See Note 1** July 2018
A.3: Ethiopia demonstration programme • *Detailed design* • *Construction* • *Monitoring & evaluation (demonstrations)* • *Demo vulnerability assessment & RAMS*	 December 2017 **See Note 1** **See Note 1** June 2018

PART B: CAPACITY ENHANCEMENT (three countries)	COMPLETION DATE
B.1: Engagement with key stakeholders in 3 countries	July 2018
B.2: Handbook, Guidelines and Manual • 1st draft • 2nd draft • Final version	 July 2017 December 2018 **April 2018**
B.3: Training modules and training workshops • 1st set of workshops • 2nd set of workshops	 February 2018 July 2018
B.4: Translation of documents in Portuguese	**March 2019**
B.5: On-site training • Trailing of Handbook and Guidelines • Vulnerability assessments (Ethiopia and Ghana) • Train-the-trainer programme	 February 2018 November 2018 **May 2019**
B.6: Journal articles & conference papers	Ongoing
PART C: ENHANCEMENT OF CAPACITY (OTHER COUNTRIES)	
C.1: Identification of priorities	Ongoing
C.2: Capacity development events	Ongoing
C.3: ReCAP website	Ongoing
PART D: EMBEDMENT	
D.1: Review of policies, strategies and plans	August 2018
D.2: Provision of advice and technical assistance • Embedment workshops • Country Reports (Ethiopia, Ghana, Mozambique)	 July 2018 (February 2018)

Note 1:

With the exception of Mozambique, the construction of the demonstration sections in Ethiopia and Ghana will not be executed in Phase 2. These concerns were raised in previous Progress Reports.

Since the focus of Phase 2 is on the demonstration and embedment of the climate adaptation methodologies proposed, it was recommended to the ReCAP PMU that sharing common understanding on vulnerability assessments and appropriate engineering designs, and the embedment thereof, are probably of greater importance right now than to construct (i.e. focus on quality control of the implementation of proposed designs) and to monitor the performance of demonstration sections, especially in view of the (apparent) challenges experienced by ERA and DFR to mobilise funding for construction of new or previously designated roads, respectively.

Several attempts were made to identify new sites in Ethiopia and Ghana that were being challenged by climate effects. These sites were used to further validate and implement the adaptation methodology through training with the expectation that the learning will be diffused nationally. These hands-on training event took place in August 2018 (Ethiopia) and November 2018 (Ghana).

The efforts that would have been devoted to the demonstration sections were redirected towards the additional documents that did not form part of the original plan (i.e. three guidelines and visual assessment manual) as well as the towards the embedment workshops and the train-the-trainer programme.

10.2 Proposed Actions for outstanding tasks and activities

The following actions will be undertaken to complete the remaining tasks and activities, which the expectation that Phase 2 of the AfCAP Climate Adaptation project will be completed by end-May 2019:

- Management and recommendations for Phase 3:
  - Completion of Draft Final report, including recommendations for Phase 3: 31 March 2019
  - Completion of Final Report: 31 April 2019
- A report on the design and construction of the demonstration sections in Mozambique will be completed after the final visit that will take place between 10 and 14 March 2019. The performance of the completed sections will also be assessed during this visit. It is expected that the report will be released towards the end of March 2019.
- The deadline for submitting comments on the Handbook, Guidelines and Manual uploaded to the ReCAP website is 31 March 2019. The comments received, as well as the feedback received from the ReCAP-appointed peer reviewers, will be processed with the expectation that final versions of these documents will be completed by end-April 2019.
- The translation of three of the five documents (i.e. Climate Adaptation Handbook, Change Management Guidelines and Climate Threats and Vulnerability Assessment Guidelines) have been translated in Portuguese, with the remaining two documents (i.e. Engineering Adaptation Guidelines and Visual Assessment Manual) expected to be completed by end-March 2019. The translated documents will be sent to ANE in Mozambique to verify the quality of the translations.
- The train-the-trainer programme has been initiated and dates have been set for the 5-day training interventions. These are as follows:
  - Mozambique: Week of 25 March 2019
  - Ghana: Week of 1 April 2019
  - Ethiopia: Week of 13 May 2019
- The translation of the Mozambican country report will be initiated after completion of the translation of the other documents, and is expected to be completed by end-April 2019.

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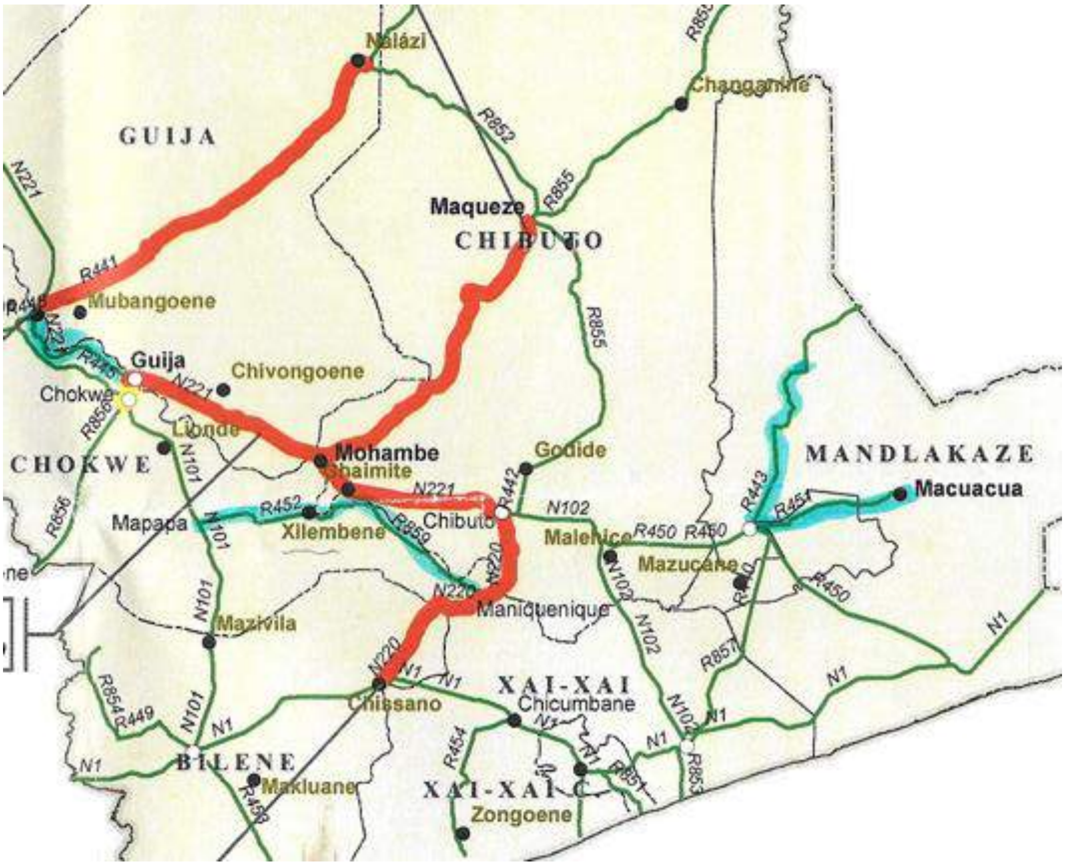
Annex 1 Progress on construction of the Mohambe-Maqueze Demonstration Sections in Mozambique

1.1 Introduction

During a visit to Mozambique in September 2016, the road between Chokwe and the dam at Chirrunduo (R440) was selected as a suitable road for the construction of demonstration sections. However, following discussions with the World Bank, it was suggested that the non-classified road between Mohambe and Maqueze be used instead (Figure 1.1). This road is in a particularly problematic area with the Changane River flowing to the east of it consisting of numerous large lakes and two large lake areas on tributaries of the Changane River to the west of the road about two thirds of the way down (Figure 1.2).

Figure 1.1 Part of Gaza province showing location of Mohambe- Maqueze road



Although this road had been identified by Mott MacDonald for a climate resilient exercise funded in a World Bank project, their conclusions were primarily related to improving the existing drainage structures and did not cover the road outside these drainage areas. The following recommendations (minimum) were made:

- Reshaping of the existing embankments so the top level of the embankment is horizontal (i.e. at a constant level)
- Reshaping of the sides of the embankment to reduce the side slopes to a maximum slope of 1:4
- Extending the existing pipe culverts to suit the wider embankment
- Construction of a 100 mm thick trapezoidal shaped concrete slab laid on the embankment slopes at each culvert inlet and outlet. The slab will extend from the road shoulder to the culvert invert. For single pipes the slabs will be 2 m wide at the shoulder and 5 m wide at the invert

- Modify the wing walls of the box culverts and drifts/fords both upstream and down using gabions, which will be turned and extended about 6 m along the toe of the embankments parallel to the road centre line (for all 4 wing walls)
- Provision of a 150 mm gravel wearing course on the road surface across the embankments (preferably calcrete gravel meeting minimum wearing course specifications)
- Planting of deep rooted local grass varieties on the embankment slopes (ideally the grass should come with the clay top soil material used to clad the embankment slopes).

Figure 1.2 Road location showing main drainage features in the area

The road was visited by the Project Team during the initial trip in September 2016 with Ms Raquel Langa (ANE, Maputo), Mr Rogerio Simione (ANE, Nampula Province) and Mr Nelson Horacio (ANE, Gaza Province). After the discussions with the World Bank, it was revisited during a trip to Mozambique between the 8th and 11th August 2017 together with Ms Raquel Langa (ANE, Maputo) and Mr Moises Dzimba (ANE, Gaza Province).

As the World Bank assessment by Mott MacDonald had specifically targeted drainage problems ANE carried out a follow up assessment and identified specific areas of the road that required attention as well. This was carried out during the wet season and thus identified various problems that would not necessarily be noticed during the dry season. ANE then prepared a detailed summary of additional work to the World Bank estimate, which is essentially a “betterment” programme. No levels or measurements were used and all estimates are based on visual assessments.

The road was revisited during a climate adaptation workshop held in Chibuto on the 20th September 2017 and additional measurements and observations were carried out.

The outcomes of the site visits and the designs proposed to the following four demonstration sections were addressed in the first Progress Report for Phase 2 (Verhaeghe et al, 2017):

1) Erosion and undercutting of the concrete ford (km 17.6)
2) Damage to road approaching concrete ford (km 36)
3) Damage to culverts and erosion protection (km 43)
4) Inadequate unpaved road providing access to Maqueze (km 51)

Progress on the construction of the four demonstration sections is presented in Section 1.2 below.

1.2 Construction

1.2.1 Erosion and undercutting of concrete ford (km 17.6)

Construction progress

The first visit was undertaken between 8 and 12 October 2018. The construction works were still at the initial stage. By the end of the visit, the following tasks had been completed.

- Foundation bed using low strength concrete for the entire ford length (approximately 50 m).
- Foundation for approximately 20 m long section.
- Preparation of formwork and fixing reinforcing steel for the 20 m long section of the wall.
- Pouring wall concrete for the first increment (approximately 1 m deep) of the 20 m long section.

Figures 1.3 to 1.8 depict construction progress by the end of the October 2018 visit.

The second visit was undertaken between 4 and 7 December 2018. By the time of the second visit, most of the construction works had been completed as depicted in Figure 1.9. Overall, the quality of the constructed concrete wall is satisfactory. However, it is recommended to construct erosion protection on the western (lake side) of the concrete wall. Furthermore, the backfill material should be levelled and compacted to ensure a smooth water flow.

Figure 1.3 Formwork preparation and reinforcing steel fixing km 17.6)

Figure 1.4 Installation of formwork support

Figure 1.5 Verification of reinforcing steel spacing

Figure 1.6 Concrete mixing

Figure 1.7 Concrete pouring and vibrating

Figure 1.8 Mould for concrete compressive strength test specimens

Figure 1.9 General view of the completed wall

Quality control test results

Quality control tests were conducted on the concrete as well as the gravel material used for backfilling. The tests were conducted by the project appointed laboratory namely Grupo de Materiais Geotecnicos (GMG). GMG laboratory also conducted the concrete mix design. The material for the concrete consisted of aggregate with 19 mm Nominal Maximum Aggregate Size (NMAS), river sand, and a 42.5 N cement class.

During construction, concrete compressive strength tests were performed on several batches. The tests were conducted 7 and 28 days after concrete casting, according to the South African Standard Test Method for Highways 1 (TMH 1) method D1. Table 1.1 provides a summary of the test results. It should be noted that the design for the ford protection wall recommended 30 MPa concrete class to be used for the construction. However, the average 28 days strength of the concrete used ranges from 25 to 27 MPa, which is considered to be satisfactory, despite being lower than the recommended concrete strength.

Material for backfilling was sourced from a borrow pit established at km 3. The Liquid Limit (LL), Plastic Limit (PL), Plastic Index (PI) and Linear Shrinkage (LS) of the material are 23, 26, 7, and 2.3 respectively. The CBR of the material at 98% MDD was 29.

1.2.2 Damage to road approaching concrete ford (km 36)

Construction progress

The contractor and consultant informed the CSIR and ANE delegation that changes were made to the design for this section. Instead of constructing the proposed RCC, the damage to the road approaching concrete ford at km 36 was repaired by constructing an improved gravel road. It was indicated that this decision was made because it was found to be cheaper than the proposed RCC.

The construction process involved:

- Excavating the existing damaged gravel road to below the concrete ford layer;
- Import improved material and compact in layers, and
- Construct 150 mm gravel wearing course.

Figure 1.10 shows the general view of the gravel road. Based on the observation made during the visit, the side slopes may require further improvement to prevent erosion. Furthermore, the side of the road near the concrete ford would have to be vegetated with indigenous grasses.

Table 1.1 Summary of concrete compressive strength test results (km 17.6)

Casting date	Days after casting	Average compressive strength (MPa)
06/10/2018	7	19.17
	28	26.36
16/10/2018	2	19.27
	28	26.91
17/10/2018	7	18.10
	28	25.45
18/10/2018	7	21.60
	28	27.07
22/10/2018	7	17.97
	28	25.08
23/10/2018	7	18.09
	28	26.45

Figure 1.10 General view of the constructed gravel road (km 36)

a) South direction

b) North direction

Quality control test results

Calcrete material used for the construction of the improved gravel road was sourced from a borrow pit established at km 39. The liquid Limit, plastic limit, plastic index and linear shrinkage of the material are 46.1, 34.5, 11.6, and 4.3 respectively. The CBR of the material at 98% MDD is 40.

During the December 2018 visit, in situ density and moisture content tests were carried out to assess the compaction quality of the improved gravel wearing course. Figure 1.11 shows the nuclear density gauge used for density and in situ moisture content measurements. The density and in situ moisture content were determined at three chainages: 0m (joint of ford and gravel road), 20m and 40m away from the ford. At each chainage, the tests were carried out on the right wheel path (RWP), the centre of the lane (CL) and the left wheel path (LWP).

Table 1.2 presents a summary of the compaction results. The specified compaction density for the gravel wearing course was 98% Mod AASHTO. The test results indicate that the compaction density achieved was generally low. The percentage compaction at the centre of the lane is generally lower than in the wheel paths. This was expected as the wearing course was constructed in July 2018; hence construction and normal traffic may have caused further densification of the gravel wearing course. Furthermore, the compaction densities appeared to decrease with increasing distance away from the concrete ford (i.e. from chainage 0m to 40m). This could be due to the slow moving vehicles near the concrete ford.

It was also noted that the thickness of the constructed wearing course ranged from 150mm to 300mm over the 40m long section as illustrated in Figure 1.12 (i.e. thicker layer closer to the concrete ford), which may have also contributed to the variations in compaction densities.

Figure 1.11 Nuclear density device

Figure 1.12 An illustration of layer thickness (km 36)

a) Closer to the concrete ford (300 mm)

b) 20 m away from the concrete ford (150 mm)

Table 1.2 Summary of field compaction results (km 36)

Distance from ford (m)	Side	Wet density (kg/m³)	Dry density (kg/m³)	Moisture (%)	Compaction (%)
0	RWP	2066	1980	4.3	97.3
	CL	1959	1880	4.2	95.3
	LWP	2039	1965	3.8	97.5
20	RWP	1980	1890	4.8	93.8
	CL	1912	1827	4.7	90.7
	LWP	2040	1943	4.2	96.4
40	RWP	1910	1808	5.7	89.7
	CL	1948	1866	4.4	92.6
	LWP	1971	1875	4.3	93.0

During the December 2018 visit, Dynamic Cone Penetrometer (DCP) tests were carried out at 0m, 10m and 20m away from the concrete ford in the northern direction, and in the left wheel path, the centre of the lane and right wheel paths respectively. Figure 1.13 shows the DCP testing, and the raw DCP data are plotted in Figure 1.14. Detailed analysis of the DCP data will be conducted in the final report.

At each of the DCP test point, soil sample was taken for laboratory determination of in situ moisture content using the gravimetric method. The moisture samples were taken from the wearing course (top) and the subbase (bottom layer). The moisture content results are presented in Table 1.3. The laboratory-determined moisture content values ranged from 5.0 to 10.9 %, and are generally lower than those measured using the nuclear gauge device.

Figure 1.13 DCP testing

Figure 1.14 DCP Results (km 36)

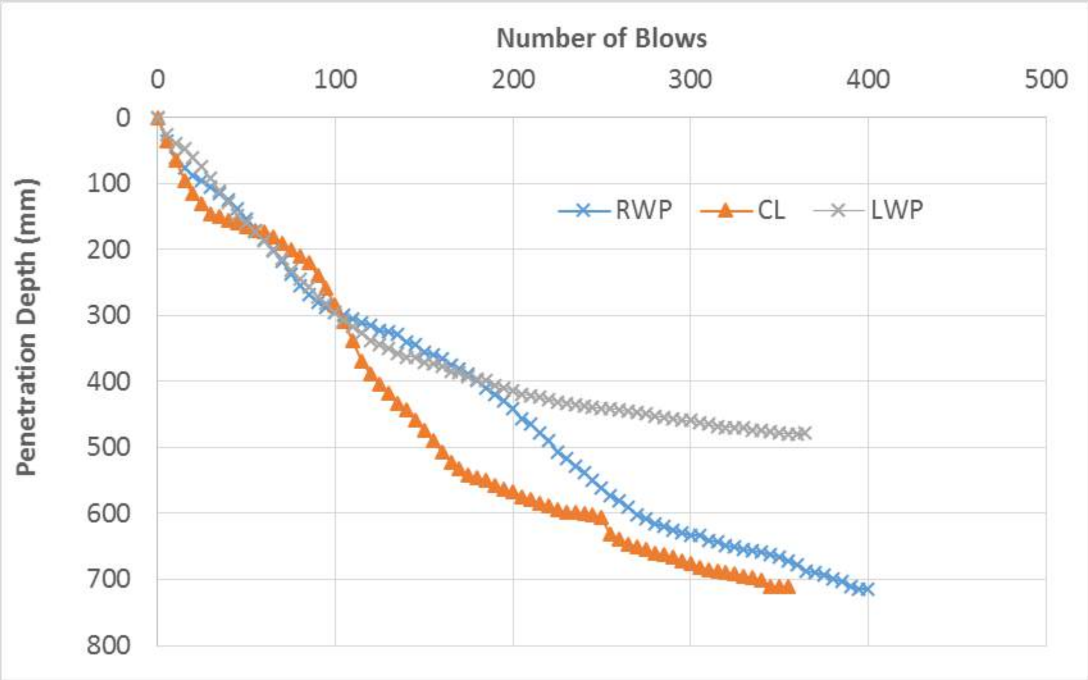


Table 1.3 Summary of moisture content results (km 36)

Distance from ford (m)	Layer	Moisture (%)
0	Top	5.0
	*Bottom	-
10	Top	6.0
	Bottom	5.4
20	Top	10.9
	Bottom	7.9

only one layer sampled because the layer thickness was greater than 300 mm.

1.2.3 Damage to culverts and erosion protection

Construction progress

By the time of the first visit in October 2018, the construction of a new culvert at km 43 was ongoing as depicted in Figure 1.15. Much of the construction progress was made during the second visit in December 2018. By end of the second visit, the following tasks had been completed:

- Construction of new culvert, including erosion protection
- Extension of wing walls of the existing culvert
- Erosion protection works for the old curvet (not yet fully completed)
- Gravel layer on top of the curvets and approaches

Figure 1.16 to Figure 1.20 depict the construction progress made by the end of the December 2018 visit. It should be pointed out that the design for the culvert protection work recommended that the beam should have been constructed first, followed by the stone pitching. This was to ensure adequate bonding between the stone pitching and the beam. However, during the implementation, the contractor constructed the stone pitching first, followed by the beam. It is, therefore, important that the performance of the bond between the beam and the stone pitching be closely monitored during the long-term performance monitoring.

Figure 1.15 Construction of erosion protection (new culvert at km 43)

Figure 1.16 General view of approach road (new culvert at km 43)

Figure 1.17 Erosion protection (stone pitching and beam) for new culvert at km 43)

Figure 1.18 General view of approach road (existing culverts at km 43)

Figure 1.19 Extension of wing walls of the existing culverts at km 43 (western side)

Figure 1.20a Erosion protection construction (stone pitching and beam) for existing culverts at km 43)

Figure 1.20b Erosion protection construction (stone pitching and beam) for existing culverts at km 43)

Quality control test results

The wearing course of the road approaching the new and existing culverts at km 43 was constructed using calcrete material sourced from a borrow pit established at km 39. During the December 2018 visit, in situ density and moisture content tests were carried out to assess the quality of the compaction. The tests were carried out at the interface of the culverts and the gravel road (i.e. 0m) and 10m away from the interface in both the northern and southern road direction. At each position, the tests were carried out in the right wheel path (RWP), the centre of the lane (CL) and in the left wheel path (LWP).

Tables 1.4 and 1.5 present a summary of the compaction results for the road approach to the new and existing culverts respectively. The compaction results indicate that the compaction density was satisfactory.

Table 1.4 Summary of field compaction results at km 43 (new culvert)

Direction	Distance from culvert (m)	Side	Wet density (kg/m^3)	Dry density (kg/m^3)	Moisture (%)	Compaction (%)
North	0	RWP	1931	1852	4.3	95.7
		CL	1999	1918	4.2	98.9
		LWP	1963	1908	2.9	98.4
	10	RWP	1988	1902	4.6	98.0
		CL	2061	1966	5.7	100.5
		LWP	1980	1881	5.5	97.0
South	0	RWP	1948	1860	4.7	96.2
		CL	2016	1918	5.1	98.9
		LWP	1990	1904	4.6	98.1
	10	RWP	2034	1919	5.8	99.1
		CL	2093	1974	6.0	101.8
		LWP	2060	1964	4.9	101.3

Table 1.5 Summary of field compaction results at km 43 (existing culvert)

Direction	Distance from culvert (m)	Side	Wet density (kg/m^3)	Dry density (kg/m^3)	Moisture (%)	Compaction (%)
North	0	RWP	2043	1903	7.3	98.1
		CL	2055	1911	7.5	98.5
		LWP	2093	1965	6.5	101.2
	10	RWP	2127	2026	5.0	104.4
		CL	2113	1997	5.6	103.1
		LWP	2119	2028	4.5	104.5
South	0	RWP	2053	1916	7.2	98.8
		CL	2056	1915	7.4	98.7
		LWP	2123	1979	7.3	102.0
	10	RWP	2078	1937	7.6	99.8
		CL	2036	1922	5.9	99.1
		LWP	2025	1895	6.9	97.7

1.2.4 Improved gravel road

Construction progress

During the October 2018 visit, the construction of new culvert at km 51 was ongoing as shown in Figure 1.21. The construction of the layer works for the improved gravel road had not yet started. By the time of the second visit in December 2018, the construction of the subbase layer of the improved gravel road was progressing. Figure 1.22 shows the construction progress made by the end of the December 2018 visit.

Quality control test results

Due to depleting good calcrete material at the quarry established at km 39, a new quarry had to be established about 10 km away from Maqueze, from the end of the road (Figure 1.23). The liquid limit, plastic limit, plastic index and linear shrinkage of the material are 23, 18, 6, and 3.3, respectively. The CBR of the material at 98% MDD is 53.

The material from the newly quarry is of marginal quality, and therefore not suitable for the construction of wearing course. The material for the construction of the wearing course will have to be sourced from the quarry at km 39.

Compaction density results are still outstanding and will be obtained during the next visit.

Figure 1.21 Construction of the a new culvert at km 51

Figure 1.22 Progress on the construction of the improved road at km 51

Figure 1.23 Borrow pit 10 km away from Maqueze

Annex 2 Training and Embedment Workshop held in Ghana

2.1 List and affiliations of staff involved

	NAME	DEPARTMENT	POSITION	E-MAIL
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2.2 Results of Vulnerability Assessments carried out: Kukurantumi – Asoka Road

Road Number:	K - A	Date:	2018/10/30	Assessors:	PPG	Weather:	C, H	Topography	F	Landcove r and use	A

Chainage	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	1,1	1,2	1,3	0,4	0,5	0,6	0,7	0,8	0,9	
Grade	Flat						Slight uphill			Slght downhill										
Access to facilities	School and clinic																			
No. of alternative roads	Yes																			
Common vehicle types	Heavy trucks (borrow pit)																			
GPS and photo No	6.189N 0.356W		#2		Shear #3,4	#5 wingwall				#6,7			6,182N 0,3638W							
Erodibility																				
Sugbrade	0	0	0	0	0	0	0	0	0	0	0	0								
Road surface - unpaved	Paved	Paved	-	-	-	-	-	-	-	-	-	-								
Side drains - unlined	-	-	-	-	5/3	0	0	0	5/3	0	0	3/3								
Embankment slopes	-	-	0	0	0	0	0	0	0	0	0	0								
Cut slopes	0	-	-	-	-	-	-	-	-	-	-	-								
Subgrade problems																				
Material type	0	0	0	0	5/3	0	0	0	5/3	0	0	3/3								
Moisture	0	0	0	0	0	0	0	0	0	0	0	0								
Drainage (in reserve)																				
Road shape	5 /4	1/5	1/5	0	5/4	5/3	5/1	1/5	5/4	1/5	1/5	1/5								
Shoulders	-	3/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5								
Side slopes	-		3/4	3/5	3/5	2/5	-	-	-	4/2	-	-								
Side drains	5/5	5/5	4/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5								
Mitre drains	-	-	-	-	-	-	-	-	-	-	0	0								
Drainage (streams)																				
Structure						0														
Approach fills						-														
Erosion of approach fills						-														
Protection works						-														
Flood plain						0														
Slope stability																				
Cut stability	0	-	-	-	-	-	-	-	-	-	-	0								
Fill stability	-	-	0	0	0	0	-	-	0	-	-	-								
Construction																				
Overall finish	3/5	0	0	0	0	0	0	0	0	0	0	0								
Erosion protection works	-	0	-	-	-	-	-	-	-	-	-	-								
Maintenance																				
Quantity	5/5	5/2	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5								
Quality	5/5	5/3	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5								
COMMENTS:																				
			Mitre drains/ chutes?		Possibly over old river bed		Culvert lined drain blocked				In cut									

Kukurantumi – Asoka Road (Continuation)

Road Number:	K - A	Date:	2018/10/30	Assessors:	PPG	Weather:	C, H	Topography	R	Landcover and use	F

Chainage	9,1	9,2	9,3			7,6	7,7	7,8	7,9	8	8,1	8,2	8,3	8,4	8,5	8,6	8,7	8,8	8,9	9
Grade							Slight downhill				Slght uphill						Crest	Sl downhill		
Access to facilities	School and clinic																			
No. of alternative roads	Yes																			
Common vehicle types						Few trucks, mostly light														
GPS and photo No						6.1736N 0.4187W					6,1732N 0,4227W					#9				
Erodibility																				
Sugbrade	0	0	0			0	0	0			0	0	0	0	0	0	0	0	0	0
Road surface - unpaved	2/2	2/2	2/2			-	-	-			2/2	2/2	2/2	2/2	2/2	1/2	1/2	1/2	2/1	2/1
Side drains - unlined	-	-	-			0	0	3/2			Lined	Silted	Silted	-	-	-	-	-	-	-
Embankment slopes	3/3	4/3	4/3			0	3/5	3/5			-	-	-	-	-	-	-	3/1	-	3/3
Cut slopes	-	-	-			-	-	-			-	-	-	-	-	-	-	-	-	-
Subgrade problems																				
Material type	0	0	0			0	0	0			0	0	0	0	0	0	0	0	0	0
Moisture	0	0	0			0	0	0			0	0	0	0	0	0	0	0	0	0
Drainage (in reserve)																				
Road shape	1/2	1/2	3/5			0	0	0			2/1	3/4	3/4	3/4	3/4	1/2	3/2	3/2	3/3	1/2
Shoulders	3/3	2/3	2/3			0	0	0			2/1	5/5	3/2	2/3	2/1	0	2/1	2/1	1/2	1/2
Side slopes	-	-	-			0	0	0			-	-	-	-	-	-	-	-	3/1	-
Side drains	0	0	0			0	0	0			0	3/4	0	0	0	0	0	0	3/1	3/1
Mitre drains	0	0	0			0	0	1/1			0	0	0	0	0	0	-	0	0	0
Drainage (streams)								Culvert												
Structure			0					0												
Approach fills			0					0												
Erosion of approach fills			0					0												
Protection works			-					0												
Flood plain			-					0												
Slope stability																				
Cut stability	-	-	-			-	-	-			-	-	-	-	-	-	-	-	-	-
Fill stability	-	-	-			-	-	-			-	-	-	-	-	-	-	-	-	-
Construction																				
Overall finish	2/5	2/5	2/5			2/5	2/5	2/5			2/5	2/5	2/5	2/5	2/5	1/5	2/5	2/5	2/5	2/5
Erosion protection works	-	-	-			-	-	-			-	-	-	-	-	-	-	-	-	-
Maintenance																				
Quantity	3/1	3/1	5/4			0	0	5/5			2/5	2/5	3/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1
Quality	2/5	2/5	2/5			0	0	3/5			2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5
COMMENTS:													350m school						Side drains partly lined	

2.3 Results of Vulnerability Assessments carried out: Anum Apapam to Obuoho

Road Number:	AA - O	Date:	2018/10/31	Assessors:	PPG	Weather:	S, H	Topography	H	Landcove r and use	PU - F

Chainage	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	1,1		Coming back	+0.100	+0.200		0	+0.100	+0.200	
Grade	St uphill	Crest	Steep downhill				Slight downhill		Flat	Slight uphill			Sag	St uphill	St uphill		Sag	Flat	Sl downhill	
Access to facilities	School																			
No. of alternative roads	No																			
Common vehicle types		Mostly motorcycles with a few cars																		
GPS and photo No	5,988N 0,585W #11,12			#14, 15			#16	#17,18	5,9926N 0,5904W				#19-31 6,0128N 0.6225W		#32 - 34 6,0129N 0,6204W		6,0103n 0,6076W			
Erodibility																				
Sugbrade	0	0	0	0	0	0	0	0	0	0	0		0	0	0		0	0	0	
Road surface - unpaved	Paved	Paved	0	3/5	4/5	5/5	5/5	5/5	2/1	3/2	3/5		Paved	Paved	Paved		3/5	0	3/5	
Side drains - unlined	5/4	3/4	3/4	3/5	4/5	0	0	0	0	0	0		0	1/1	0		0	-	-	
Embankment slopes	-	-	-	-	-	-	-	-	-	-	-		0	-	-		0	-	-	
Cut slopes	-	-	-	-	-	-	-	-	-	-	-		0	-	-		-	-	-	
Subgrade problems																				
Material type	0	0	0	0	0	0	0	0	0	0	0		0	0	0		0	0	0	
Moisture	0	0	0	0	0	0	0	0	0	0	0		0	0	0		0	0	0	
Drainage (in reserve)																				
Road shape	0	0	0	2/5	4/5	5/5	5/5	5/5	5/2	5/5	5/5		0	1/1	0		5/5	5/5	5/5	
Shoulders	-	-	-	-	-	-	-	-	-	-	-		Sealed	Sealed	0		-	5/5	-	
Side slopes	-	-	-	-	-	5/5	5/5	2/3	5/3	5/3	5/3		0	0	-		0	-	-	
Side drains	3/5	1/5	1/5	3/5	4/5	4/5	5/5	5/5	0	0	0		0	0	0		0	-	-	
Mitre drains	-	-	-	-	-	-	-	-	-	-	-		-	-	0		-	-	-	
Drainage (streams)									culvert				culvert +30m		culvert +40 m					
Structure									?				0		?					
Approach fills													0							
Erosion of approach fills									0				0		4/1					
Protection works									-				0							
Flood plain									-				0		-					
Slope stability																				
Cut stability	-	-	-	-	-	-	-	-	-	-	-		-	-	-		-	-	-	
Fill stability	-	-	-	-	-	-	-	-	-	-	-		-	-	-		-	-	-	
Construction																				
Overall finish	0	0	3/5	3/5	4/5	4/5	4/5	4/5	4/5	4/5	4/5		0	3/5	3/5		5/5	5/5	5/5	
Erosion protection works	2/5	-	-	-	-	-	-	-	-	-	-		-	-	-		-	-	-	
Maintenance																				
Quantity	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5	5/5		5/5	5/5	5/5		5/5	5/5	5/5	
Quality	-	-	-	-	-	-	-	-	-	-	-		-	-	-		-	-	-	
COMMENTS:																				
	Side drains partly lined but damaged							Width reduced 8m - 3m	GPS at culvert - overgrown				Overtopped once in 3 years - waist high water for a few hours	Poor off-road drainage						

2.4 Results of Vulnerability Assessments carried out: Akwesiho to Twenedurase

Road Number:	A - T	**Date:**	**2018/11/01**	**Assessors:**	**PPG**	**Weather:**	**PC, H**	**Topography**	**M**	**Landcover and use**	**N**

Chainage	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	1,1	1,2	1,3	1,4	1,5	1,6				
Grade	Crest	St downhill		V Steep downhill					VV steep down				V Steep down							
Access to facilities	Villages																			
No. of alternative roads	2																			
Common vehicle types		Couple of cars - very steep																		
GPS and photo No	6,6172N 0,7966W		#36		# 37,38	#39,40	#41 - 44		#45-47	#47-51				# 52, 53		6,621N 0,8015W				
Erodibility																				
Sugbrade	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Road surface - unpaved	0	0	0	0	0	0	0	0	3/3	2/2	4/3	4/5	4/5	1/1	1/1	0				
Side drains - unlined	-	-	-	2/3	0	0	2/2	2/2	3/1	3/5	5/5	5/5	5/5	-	-	-				
Embankment slopes	-	-	3/1	-	-	-	-	-	5/2	5/1	-	-	3/1	3/1	0	2/1				
Cut slopes	-	1/3	-	0	0	0	0	0	0	0	0	1/2	1/1	0	2/1	0				
Subgrade problems																				
Material type	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Moisture	0	0	0	0	2/3	3/2	3/5	0	5/1	5/2	0	0	0	0	0	0				
Drainage (in reserve)																				
Road shape	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Shoulders	0	0	0	0	0	5/3	0	0	0	0	0	0	0	0	0	0				
Side slopes	5/5	5/5	5/5	0	0	-	0	3/3	5/2	5/3	1/5	1/5	1/5	0	0	0				
Side drains	-	-	-	0	0	3/1	3/1	0	0	5/1	0	0	0	0	0	0				
Mitre drains	-	-	1/1	-	-	-	-	-	-	-	-	-	0	-	-	-				
Drainage (streams)																				
Structure																				
Approach fills																				
Erosion of approach fills																				
Protection works																				
Flood plain																				
Slope stability																				
Cut stability	-	-	-	1/1	1/5	5/5	4/3	-	0	0	0	0	0	0	0	0				
Fill stability	-	-	-	-	-	-	-	-	-	0	0	0	-	-	-	0				
Construction																				
Overall finish	0	1/5	2/5	3/5	3/5	3/5	3/5	3/5	3/5	3/5	4/5	4/5	4/5	4/5	2/5	1/5				
Erosion protection works	-	-	-	-	-	-	-	-	-	-	-		-	-	-					
Maintenance																				
Quantity	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A				
Quality	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A				

COMMENTS:

New road

2.5 Summary of activities (Dr P Paige-Green)

October 28th, 2018

- 16h00 – Depart for airport
- 18h30 to 22h30 (24h30 SA time) Fly to Accra – Prepare presentations

October 29th, 2018

- 08h30 – Depart from Accra for Koforidua and check in at hotel
- 14h00 to 16h30 – Briefing session at Koforidua Training Centre

October 30th, 2018

- 08h30 – Pick up at hotel and go to EKTC
- 09h45 – 14h00 – Assessment of 2,8 km of Kukurantumi – Asoka road
- 16h30 – Return to hotel

October 31st, 2018

- 08h00 – Leave hotel for KTC
- 08h30 – 14h15 - Assessment of 1.7 km Anum Apapam – Obuoho road
- 16h00 – arrive back at hotel

November 1st, 2018

- 07h45 – 10h00 – Meet and drive to Akwesiho – Twenedurase road
- 10h00 – 13h50 – assess 1.6 m of road
- 13h50 – 15h00 – Return to KTC
- 15h45 – Return to hotel
- 16h30 – 22h00 – analyse results and prepare presentation

November 2nd, 2018

- 07h45 – 13h45 – KTC – Analysis and discussion
- 14h15 – 16h00 – Prepare summary report

November 3rd, 2018

- 14h45 – Depart Koforidua for Kotoka Airport, Accra and catch 22h30 flight to OR Tambo
- Arrive in South Africa on 4th of November at 08h00

2.6 Course evaluation and responses received

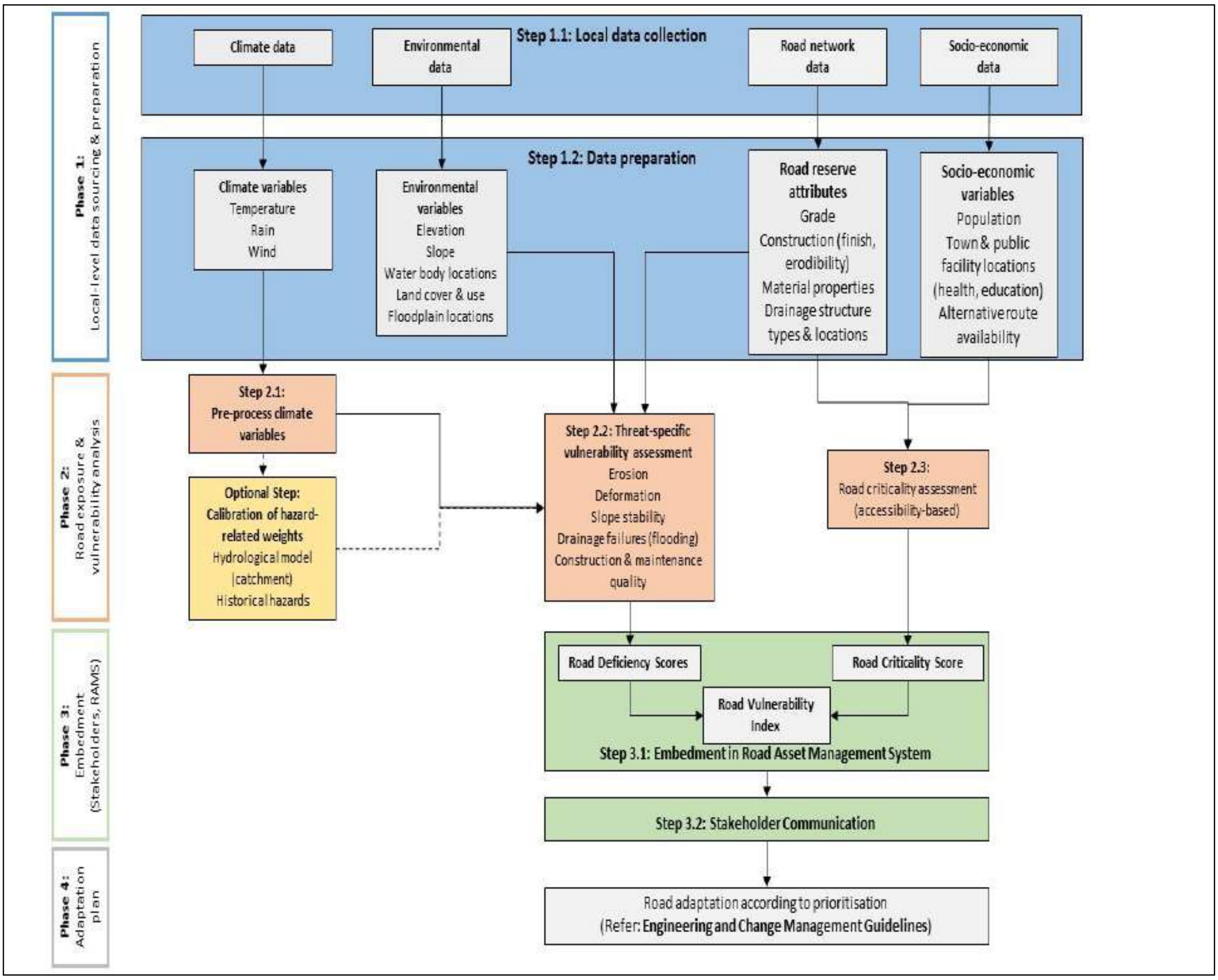
	1	2	3	4	Mean
1. Training	**1**	**2**	**3**	**4**	**Mean**
The objectives of the training were generally achieved	3	2	2	1	2,0
The classroom presentations were well presented and understood	2	2	1	2	1,8
I have obtained a good understanding of the vulnerability assessment for climate change adaptation	2	2	2	1	1,8
I have obtained a good understanding of the use of the data for climate resilience adaptation designs	3	2	2	2	2,3
I have obtained a good understanding of the manner of carrying out a vulnerability assessment in the field	1	2	2	1	1,5
The facilitator was competent to present the course	1	1		1	1,0
There was enough time for practical assessment exercises in the field and for discussions/clarifications	3	1	3	1	2,0
2. Field Trip and Classroom exercises					
The field trip was well organized	2	2	2	1	1,8
I have obtained a good understanding of how to undertake field assessments	2	2	2	1	1,8
I found the field trips to be useful	2	2	1	1	1,5
3. Organisation					
I found the arrangements for accommodation/conference facilities for the course to be satisfactory	3	2	3	1	2,3
I was given satisfactory support from my organization to participate in the course.	4	2	2		2,7
I found the course to be generally well organized (travel, food, etc).	2	2	3	2	2,3
4. Venue					
The classroom facilities were satisfactory	2	2	2	2	2,0
The practical training was well organised.	2	2	2	2	2,0
5. Miscellaneous					
The vulnerability assessment process identifies appropriate inputs for the climate adaptation needs and design	3	2	1	2	2,0
I need more training to become a competent practitioner in designing climate resilient adaptation methods	2	2	2	3	2,3
I am genuinely interested in becoming a future Trainer in my country in the implementation of climate resilient design	2	1	2	1	1,5
6. General comments					
Do you have any other general comments on the course?					
1.			Notification was too short	Training should involve others than road engineers	
2.			More prepartion by participants		
Notes: 1 = Totally agree. 2 = Agree. 3 = Partially Agree. 4 = Partially disagree. 5 = Totally disagree					

Annex 3 Development of a Vulnerability Index

3.1 Implementing the local level vulnerability assessment framework: general

The local assessment framework as presented in the *Climate Threats and Vulnerability Assessment Guidelines* (le Roux et al, 2018) consists of four phases (see Figure 3.1). This differs from the district level assessment presented in these Guidelines in two ways. Firstly, the local assessment accommodates the possibility that local level spatial data on historical hazards (or disasters) will in most cases not be available, in contrast to the availability of EM-DAT disaster data used for the district level assessment. In cases where these datasets are available at the local level, they will be used as weights when quantifying vulnerability to specific climate threats. For example, if the area is flood prone, spatial layers for rainfall variables will be given more weight in quantifying vulnerability in terms of the five specific threats. If there is no reliable historical disaster dataset, then the climate variables can be considered uniformly. Secondly, the assessment considers the vulnerability of rural roads to specific climate-related threats and these can be mapped for particular road network catchments. Disaggregation of vulnerability according to threats is necessary at the local level because the aim is to provide information that the engineers can use when making design-related decisions.

Figure 3.1 A conceptual framework for the local vulnerability assessment of rural access roads



Observed climate, socio-economic and road attribute data can be used for the current situation analysis. The difficulty is with future scenario assessment, because ideally this requires high spatial resolution projections on the climate, the population, planned road infrastructure projects, facilities and changes in land use. The resolution of climate projections is typically too coarse at 50 km, while demographers are reluctant, for reasons of reliability, to produce sub-national population projections. Therefore, future scenario assessment can either be restricted to using current data with projections on those variables where these are available or implementing a simulation-based futures analysis based on specific climate, demographic and spatial planning scenarios formulated through engagements with the relevant experts and stakeholders. Either way, the uncertainty associated with future estimates of threats and vulnerability indices will be high.

A new methodology for calculating a multi-dimensional Vulnerability Index for rural access roads is proposed in the sections that follow. They focus on Steps 2.2, 2.3 and 3.1 of the conceptual framework presented in Figure 3.1. Information on the other Steps can be found in the *Climate Threats and Vulnerability Assessment Guidelines* (le Roux et al, 2018).

Step 2.2: Threat-specific vulnerability assessment

Aim:

The aim of this step is to conduct a road exposure and vulnerability assessment of specific climate threats. Information on the variability of vulnerability to specific threats along the road helps in deciding where to implement specific engineering adaptation options and changes in land-use practices to reduce the extent of damage resulting from adverse climate events. The vulnerability of rural road infrastructure to the following climate threats is considered:

- Flooding of the road surface due to drainage failure;
- Erosion of embankments and foundations; and loss of pavement integrity through cracking and/ or aggregate loss;
- Deformations resulting from subgrade material and moisture defects;
- Deficiencies in slope stability; and
- Poor quality construction and maintenance.

Recommendations:

Transforming defect variables

There are two levels to the local vulnerability assessment. The first level of the assessment considers the current situation of road defects that render the road vulnerable to climate effects, whereas in the second level the effects of changes in climate, population and land-use are evaluated. For the current situation assessment, threats for each road segment are calculated using data in RAMS that were collected through the resilience visual condition assessment forms. Tables 3.1 and 3.2 show descriptions of how defects are evaluated (rated) during the condition assessment. Therefore, for each segment there are several defect variables and for each variable there are two observation, namely severity and extent as shown Figure 3.2. These data are to be reclassified (Step 1.2) into single-observation variables using rating/scoring rules as follows:

i. Any road segment with a severity rating of 5, needs urgent attention. In particular, it needs reconstruction and adaptation for improved resilience to climate threats.
ii. For severity ratings 1-4, the combined rating is the uniform geometric mean which in this case is the square root of the product of severity and extent. The use of the geometric mean corresponds to the multiplicative nature of severity and extent in the context of deficiencies or damage.

Once the two-part defect ratings have been converted into singular ratings, they can be aggregated into climate threat specific vulnerability factor scores as illustrated in Phase 2 of the local assessment methodology framework (Figure 3.1). For example, there will be higher vulnerability to erosion (high erodibility scores) for segments where side drains are unlined. Considering the road surface height, the lower it is, the more prone it is to flooding, unless it is intentionally shaped to cater for overtopping; hence, flood plain locations and where the road shape is inadequate for drainage would be scored higher for drainage vulnerability which may be interpreted as higher flood risk. Lack of erosion protection works, especially on steep slopes, embankments and areas where erosion is present, would be scored unfavourably in terms of vulnerability to erosion.

Table 3.1 General description of degree classification (Paige-Green et al, 2018)

Degree	Severity	Description
0	-	No potential vulnerabilities visible
1	Slight	Only the first signs of distress are visible but these are difficult to discern. No adaptation measures necessary
2	Slight to warning	Distress obvious but not at degree 3
3	Warning	Start of secondary defects. (Distress notable with respect to possible consequences). Adaptation in the medium term may be necessary. Usually requires repair
4	Warning to severe	Secondary defects clearly visible but not at degree 5 yet
5	Severe	Secondary defects are well developed (high degree of secondary defects) and/or extreme severity of primary defect. Adaptation measures should be implemented immediately. Usually requires reconstruction

Table 3.2 General description of extent classification (Paige-Green et al, 2018)

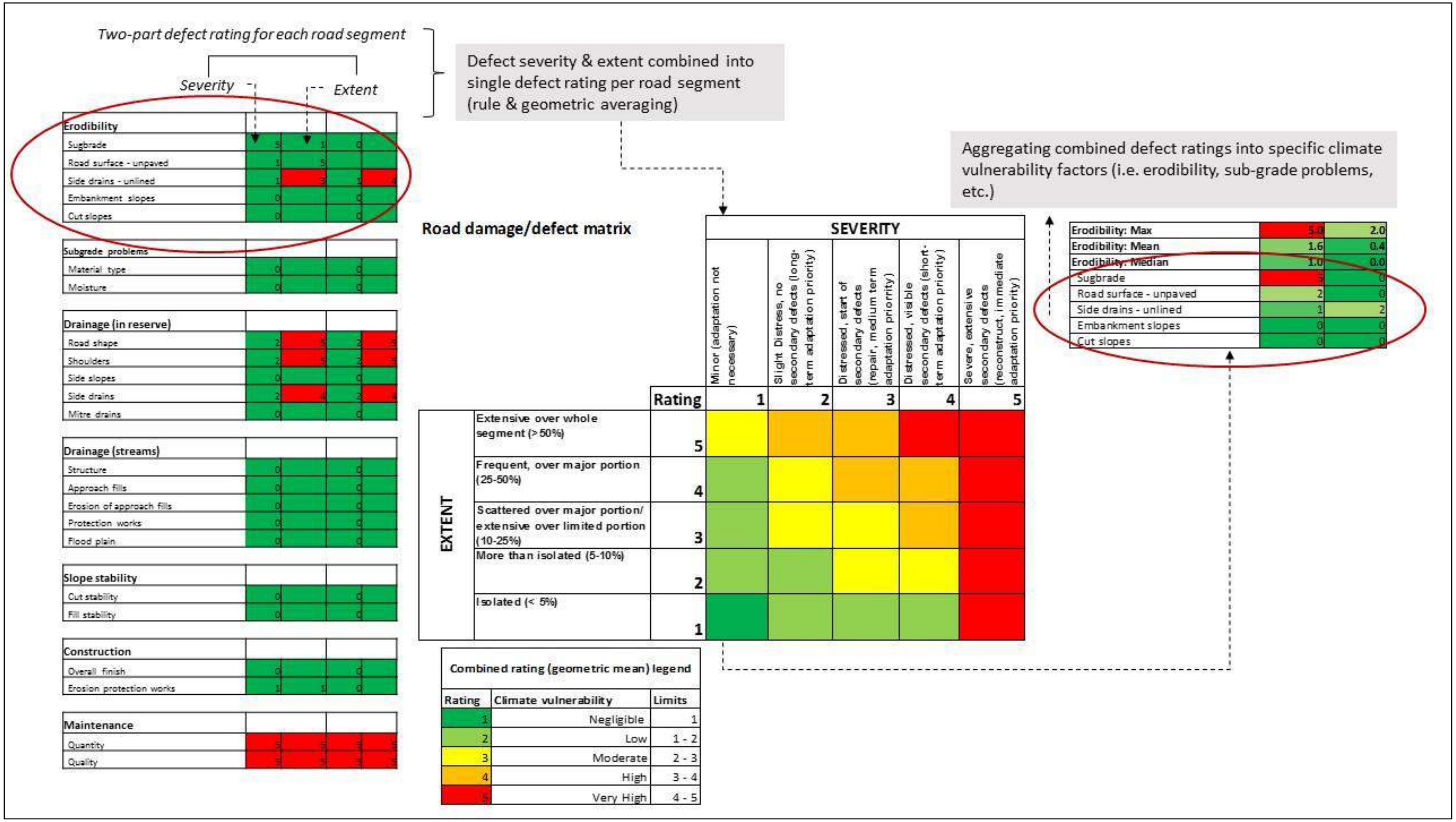
Extent	Description	Percentage of length *
1	Isolated occurrence	< 5
2	Occurs over parts of the segment length More than isolated	5 - 10
3	Intermittent (scattered) occurrence over most of the segment length (general), or Extensive occurrence over a limited portion of the segment length.	10 - 25
4	More frequent occurrence over a major portion of the segment length	25 - 50
5	Extensive occurrence over the entire segment	>50

The percentage of extent is only a guide-line for the assessors and should not be literally interpreted

Aggregating defect ratings

The maximum function is recommended for aggregating defect ratings into respective vulnerability factor scores because of its non-compensatory property where the presence of a serious defects (high rating) is not diluted when the other defect ratings for that particular factor are zero or very low. Figure 3.2 shows three erodibility factor scores obtained using the maximum, arithmetic mean and the median functions to illustrate the effect of using either function, evaluating in particular whether the resulting scores are representative of the patterns observed at the defect level. Arithmetic averaging results in dilution or over-smoothing, whereas the median is biased towards the most frequently occurring values (zero in this case) and is insensitive to the presence of a small number serious defects.

Figure 3.2 Transformation of road condition defect severity & extent ratings into a combined rating for each defect variable per road segment



Land cover and use data are also collected during the condition visual assessment and there is an option to consider these in quantifying climate vulnerability. Land cover has an effect on surface water run-off and therefore important to consider for vulnerability to floods. Therefore, one way to incorporate land cover information that is proposed in these guidelines is as a multiplicative factor on drainage factor scores. For that purpose, ratings of land cover described in Table 3.3 were developed in terms of effects on rainwater run-off (Falemo et al, 2015; Paige-Green et al, 2018).

Table 3.3 Rating land cover from the perspective of vulnerability to flooding of rural access roads

Land-cover	Rating	Reasoning
Natural forest	5	Permeable soil and vegetation associated with appropriate channeling of run-off into streams and seepage into acquifers
Dense forest	4	Water can seep through the soil, but dense vegetation can be an obstacle and cause road to be inundated
Agriculture	3	Water can seep through the soil, but clearing of natural vegetation increase run-off and erosion
Degraded land	2	Degraded land associated with ncreased run-off and erosion
Peri-urban (PU)	1	Peri-urban areas have larger built-up/ impervious surface footprint - associated with increase run-off

Step 2.3: Road criticality assessment (based on rural accessibility and remoteness)

Aim:

Road criticality pertains to the importance of that particular road for access to markets and public facilities. At the local scale, a narrative about the community's use of a particular road is important to put into perspective the losses incurred by the community when access is interrupted due to climate events. In terms of the multi-dimensional vulnerability index illustrated in Figure 3.3, the socioeconomic importance of the road in terms of access and connectivity to rural areas is considered as the third dimension.

Recommendations:

Alternative access and connectivity

For rural access, the availability of an alternative route is important, especially for emergency situations to prevent the loss of lives as well as to maintain connectivity during periods where a particular access road becomes impassable. For the local vulnerability assessment, the availability of alternative routes is assessed in conjunction with the status of connectivity to higher order roads as shown in Figure 3.4. Criteria for rating criticality in terms of connectivity and the number of alternative routes available are based on the typical functional classification of rural roads (COTO, 2012; Sadeque et al, 2017) and consideration of the strategic needs of stakeholders (ICF International, 2014; Head et al, 2018b). When there are no alternative routes, the road is classified as critical regardless of the order of the road it provides connection to. This is based on the premise that isolated rural villages are often hotspots of extreme poverty and if the aspiration to stimulate socioeconomic development in rural areas and prioritize serviceability and accessibility to normal focal and emergency points as stated in the *Change Management Guidelines* (Head et al, 2018b), then if there are no alternatives then the road being evaluated rates highly in terms of criticality. The remainder of the scores in Figure 3.4 are obtained by geometric averaging of ratings for connectivity and number of alternative routes.

Figure 3.3 The rural road vulnerability index integrates three dimensions: road condition deficiency, maintenance & criticality. The fuzzy edges represent higher uncertainty associated with climate, environmental and population change.

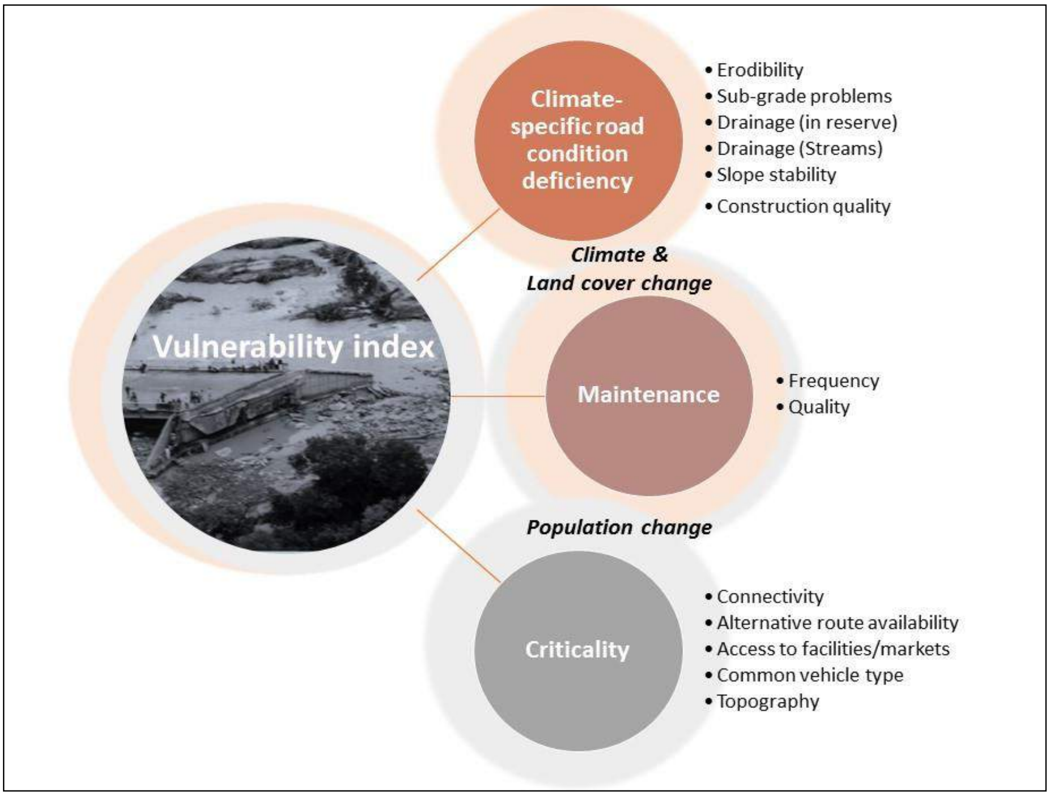


Figure 3.4 Evaluating the criticality of rural access, considering the availability of access routes & network connectivity

			Higher order connectivity			
			None (may be local road connection)	Collector road (access road, connecting rural settlements)	Minor distributor	Major distributor
Alternative route availability	No.	Crit. Rating	1	3	4	5
	0	5	5	5	5	5
	1	4	2	3	4	5
	2	3	2	3	3	4
	>2	1	1	2	2	2

Another aspect to consider is the type of traffic that is common on a particular road. It is common to consider this variable in assessing performance against serviceability standards. In this case, common vehicle type is considered from the perspective of rural access roads as enablers of access and throughput in the sense that rural areas should have connections to the larger region, namely other villages and markets/towns (Taylor, 2017). The criteria for rating common vehicle types (Table 3.4) are based on the type of goods and destination that would typically be transported by a particular class of vehicle as well as the expected impact such vehicles would have on roads.

Table 3.4 Criteria for the criticality of roads based on common vehicles types observed during the assessment.

Common vehicle types	Criticality Rating	Reasoning
Trucks	5	Transport of goods to intra/inter regional markets/ growth centres; Heavy loads - greater impact on road condition
Light duty	4	Transport of goods to local market/s; Moderate loads -
Motor cars	3	Transport of people for work or other social reasons; Moderate impact on road if traffic is more than expected
Carts	2	Trnasport of goods within or between village; Less than moderate - heavier loads may be seasonal (harvest)
Bi/motorcycles	1	Local travel; Light load - least impact on road condition

Access to markets and public facilities

Another variable considered in evaluating criticality is access to public facilities and to markets. The latter can be interpreted as places where goods can be traded or employment centres which facilitate improved living standards and strengthens the regional economy. Table 3.5 consists of criteria that are developed for rating the criticality of access to these focal points. For the rating criteria the order of the socioeconomic functionality of the focal points was considered, integrating human development objectives with consideration of the size of the population that benefit from the services (CSIR, 2000; (Sadeque et al, 2017).

Table 3.5 Criticality criteria for access to markets and public facilities

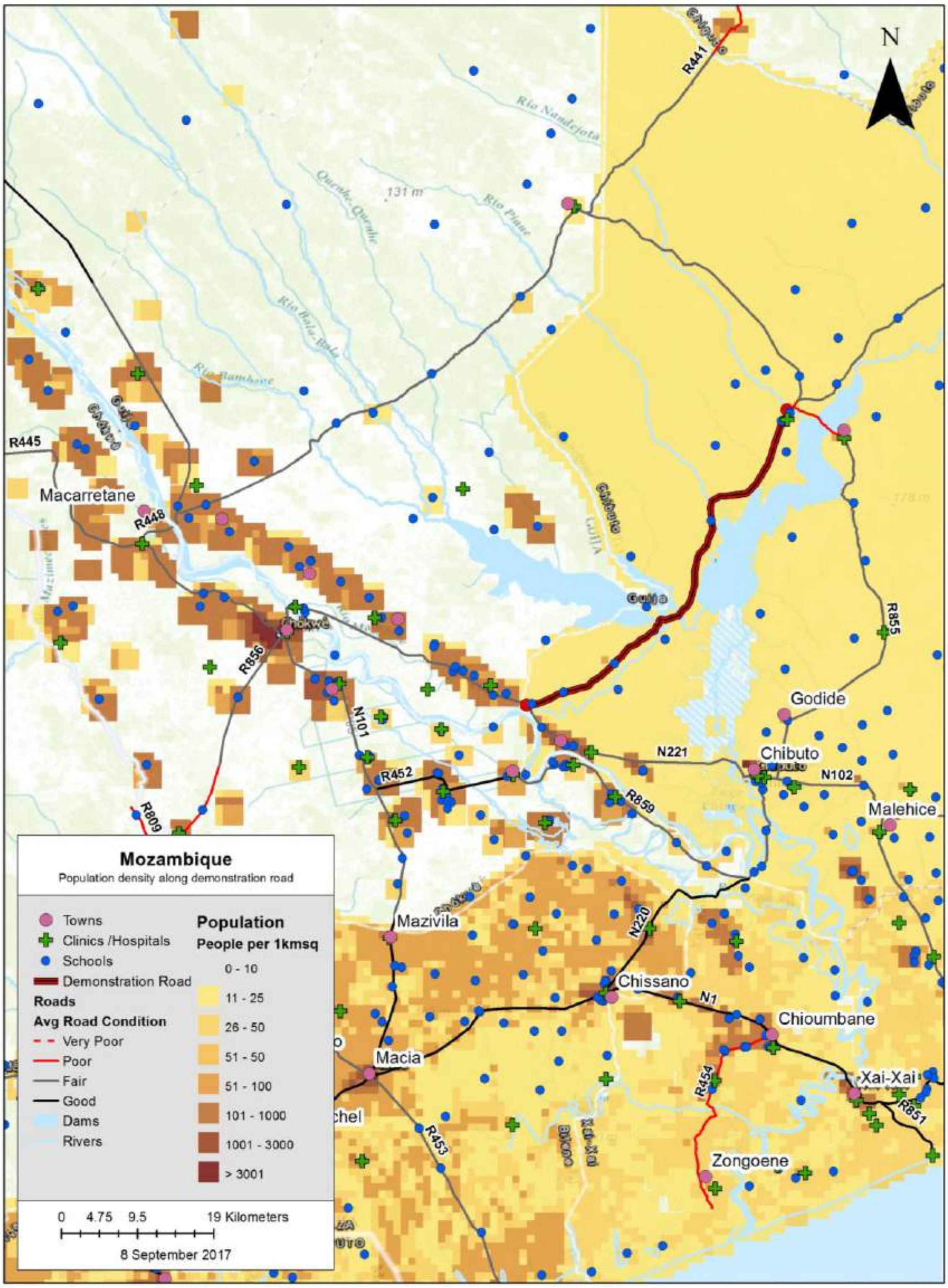
Public Facility	Crit. Rating	Criteria	Reasoning
Market/town	5	Economic productivity & development	Stimulation of rural economic participation & growth through access to markets for trading goods, jobs and social welfare services
Health/safety centres	4	Safety & improved quality of life	Reduced mortality and morbidity; Disease and crime prevention
School	3	Investment in improved socioeconomic outcomes	Investment in the next generation's ability to be economically active; schools also typically serve as emergency stations
Cultural/ recreational	1	Community development	Cultural or recreational facilities e.g. community hall

Figure 3.5 shows that the road segment between Chibabel and Maqueze is a critical link to the N221 along which several towns, education and healthcare facilities are located in both the northerly direction towards Macarretane and in the southerly direction towards Chibuto. The areas immediately adjacent to the Chibabel–Maqueze road section are sparsely populated with no town and healthcare facilities.

Figure 3.5 An indication of the population distribution and the location of towns and education and healthcare facilities within the catchment of the Chibabel and Maqueze road segment

Population distribution and the location of towns, education and healthcare facilities

Population density and socio-economic facilities along road between Chibabel and Maqueze,Gaza Province, Mozambique



Data source: CSIR (2017), WorldPop 2010

Topography as a criticality variable

In this case criticality is rated based on a view that a road may have a high risk of impassability as a result of the topography of its location. For example the risk of landslides following long durations of persistent heavy rains in mountainous areas is high. Therefore, roads in mountainous regions are rated high in terms of criticality (Table 3.6) due to the increased risk that villages can be cut-off and making it difficult for these communities to move goods in the absence of the roads.

Table 3.6 Considering topography as a criticality variable from the perspective of prolonged loss of access resulting from topography sensitive climate threats

Topography	Rating	Criteria	Reasoning
Flat	1	Flood inundation	Higher risk of inundation due to heavy rain
Rolling	3	Slope failure, erosion	Surface water run-off during heavy rain; risk of erosion & slope failure
Mountainous	5	Slope failure, erosion	Increased surface water run-off; higher risk of erosion & slope failure

Phase 3: Embedment into Road Asset Management Systems

Aim:

In this phase, the aim is to embed vulnerability and criticality indices into road asset management systems. In this way, climate change can be considered as a risk when using data from the RAMS for planning.

Recommendations:

- An understanding of the RAMS database structure would be required during this phase.
- It would be essential for the person appointed to do the spatial data analysis to have close interaction with the RAMS champion(s) or persons managing the RAMS.
- Changes to the RAMS database structure would be required to accommodate climate change data. Alternatively the climate change (future) assessments can be done in a GIS and only the resulting deficiency, criticality and vulnerability indices can be imported into the RAMS.

Step 3.1: Prepare and export data to RAMS

Aim:

The aim of this step is to match the threat-specific factor scores and vulnerability indices, calculated in Phase 2 per road segment, to the correct roads in the RAMS where data (attributes) are stored per road link. This implies that decision-makers at the network level will have insights on the overall degree of vulnerability of roads, including current structural defects, as well as insights into the function of different roads in terms of access and connectivity. The vulnerability index illustrated in Figure 3.3 integrates three composite indicators, namely an indicator of road condition deficiency to the impacts of climate, an indicator of maintenance efficacy, and an indicator of the criticality of the road. The solid circles represent the current situation (or first level of the assessment using observed data) where lower uncertainty is associated with the indices, while the fuzzy edges represents an expectation of increased vulnerability in the future with higher degrees of uncertainty given uncertainties about climate, population and land cover change.

Recommendations:

- Establish a one-to-one link between the road data in the GIS and road links in the RAMS database.
- Allocate the deficiency factor scores and road criticality scores to the road link in the RAMS database, using the one-to-one link.

- Link calculated hydrological data, such as run-off for different return periods, to the correct river bridges and major culverts by way of coordinates.
- Export the climate and population change indicators from the GIS in a format that can be imported into the RAMS (Road Asset Management System) and BMS (Bridge Management System) databases.

Calculating the multi-dimensional vulnerability index

The composite indicator of climate specific deficiencies in road condition in Figure 3.3 is an aggregation of specific vulnerability factors that represent the physical/structural insufficiency of the infrastructure to withstand negative climate impacts. Maintenance is considered independently from this dimension because unlike the physical state of the road (which can be thought of as an object), maintenance is a continuous process whose frequency and quality has a direct impact on the longevity of road infrastructure (Burningham & Stankevich, 2005). Further, maintenance regimes are shaped by the availability of resources, as well as differences in policy planning and implementation practices and therefore it is an important change management consideration (Head et al, 2018b). Separating maintenance from structural deficiency also enables exploration of the effect of different types of maintenance regimes which is useful in strategically planning for the future (Qiao et al, 2015; Taylor & Philp, 2015). In most developing countries, particularly in Africa, budgets are often insufficient for the levels of maintenance required (Gwilliam et al, 2008). Therefore, this indicator is expected to be high (ratings of 4 or 5) for most rural roads. The third dimension is that of the importance of the road in terms of providing access and connectivity of rural settlements to the rest of the region. This is discussed in detail in Step 2.3.

For the **current situation** the vulnerability index is calculated as follows:

- Calculate the deficiency score (DI) as the median of the erodibility, drainage, subgrade, slope stability and construction quality factor scores. Recall that the factor scores were calculated as maxima of the defect values for that factor.
- Calculate the criticality score (Cr) as the geometric average of ratings for the following variables: alternative route and connectivity, common vehicle types, access to facilities and topography.
- The vulnerability index (VI) which ranges from 0 to 5 is calculated as a weighted geometric average (the weights can be changed) of the aggregate deficiency, maintenance (Mn) and criticality scores as follows:

  $$VI = DI^{0.70} \times Mn^{0.15} \times Cr^{0.15}$$

For the **future situation** taking into account climate and population change, the vulnerability index is modified multiplicatively based on scenario modifications in the deficiency, maintenance and criticality scores. The scenario approach is preferable as one can choose for example, the low, median and high population growth to account for uncertainty in population projections and therefore derive criticality scores corresponding to the different growth trajectories. Similarly in the case of climate change there is a choice of using output from an ensemble of climate simulation models and in that way incorporate the uncertainty associated with climate projections into the deficiency and maintenance indicators. It is recommended that scenarios for climate and population change be limited to 3 as this already results in 9 permutations for the vulnerability index.

For each permutation of climate and population changes re-assessment of vulnerability is as follows:

- The deficiency factors are individually adjusted based on a grading framework as follows:
  - Increase vulnerability (+1)
  - No increase vulnerability (0)
  - Decrease in vulnerability (-1)
- For example, if as a result of climate change the return period for a design rainfall event is shortened where the road is located, then an increase in vulnerability to flooding is expected hence the drainage score would need to be increased (+1).

- The vulnerability grading scheme also applies for possibilities considered regarding the implementation of maintenance procedures.
- Adjustment of the criticality score should be based on plans for new public facilities and emerging growth centres from the population projections.
    - Increasing criticality (+1) can be based on the combination of population growth and increases in facility;
    - No change in criticality can be associated areas of low population growth
    - Decrease in criticality (-1) would be characterised by areas of rapid population decline
- The lower and upper limits in the scenario analysis using both the vulnerability and criticality grading are 0 and 5. This means that if in the current situation erodibility for a particular road segment is 5 and it is projected that the area will become more vulnerable to erosion due to climate change, the erodibility score would remain 5.
- Once adjustments pertaining to each permutation of climate and population change have been made, the aggregate deficiency, maintenance and criticality scores can be calculated and then geometrically averaged to get the vulnerability index. If there were 9 permutations, there will be 9 indices which can be mapped to assess difference and communicate with the stakeholders.

Annex 4 Example of invitation letter for the train-the-trainer programme

Thursday, 21 February 2019

Mr Tamba Amara
Chief Engineer
Feeder Roads Development
Sierra Leone Roads Authority
Kissy Bye-Pass Road, Kissy
Freetown
Sierra Leone

Dear Mr Amara,

Participation by Sierra Leone in a Train-the-Trainer Programme: AfCAP Climate Adaptation Project – GEN2014C

Sierra Leone, as an AfCAP Partner Country, has to benefit from the outcomes of the AfCAP Regional Project on Climate Adaptation. To support the sharing thereof in the current phase of the project we will hold a one-week train-the-trainer programme in Koforidua, Ghana, to capacitate experienced trainers from Sierra Leone, the Democratic Republic of the Congo, Ghana and Liberia. A similar programme will also be led for the other eight AfCAP Partner Countries.

We would appreciate it very much if you could identify up to three suitable trainers from Sierra Leone for the programme, which will be held from Monday, 01 April 2019 to Friday, 05 April 2019. Please also send copies of their passports so that we can make their travel arrangements.

The one-week programme will aim to capacitate the trainers with the required knowledge to disseminate current best practices on how to deal with the effects of climate change on low-volume rural road networks.

These best practices are captured in the following series of documents which will form the basis of the training: (a) a Climate Adaptation Handbook; (b) Change Management Guidelines; (c) Climate Threats and Vulnerability Assessment Guidelines; (d) Engineering Adaptation Guidelines; and (e) a Visual Assessment Manual.

For more details, please see the attached summary document, as well as the project's web site: http://www.research4cap.org/SitePages/Climate%20Adaptation.aspx.

Your assistance in facilitating the above at your earliest convenience will be highly appreciated.

Yours Sincerely,

Benoît Verhaeghe Pr Eng
Team Leader: AfCAP Climate Adaptation Project
Competence Area Manager: Transport Infrastructure Engineering
CSIR Built Environment

Train-the-Trainer Programme

AfCAP Climate Adaptation Project – GEN2014C

Background

The Africa Community Access Partnership (AfCAP), a research programme funded by UKAid, commissioned a project 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 rural road network that reaches fully into and between rural communities. The project is led by the South African Council for Scientific and Industrial Research (CSIR) on behalf of AfCAP.

Previous outputs from this project (Phase 1) included an overview of current and projected climate threats and their impact on low-volume road infrastructure, particularly for the three AfCAP Lead Countries for this project, namely Ethiopia, Ghana and Mozambique; risk and vulnerability assessment methodologies; adaptation methodologies; and engineering and non-engineering adaptation options. Preliminary work was also done to establish demonstration sections in the three AfCAP Lead Countries, followed by workshops held in these countries. The purpose of these workshops was to assess and trial these outputs as well as to identify the countries' priorities for uptake and embedment.

The focus of the project during Phase 2 has been on the demonstration of appropriate practices in the three AfCAP Lead Countries, capacity building, and the uptake and subsequent embedment of outcomes at a range of levels, from informing national policies, through regional and district planning, down to practical guidance on adaptation delivery at rural road level. The demonstrations largely focussed on demonstrating the vulnerability assessment and climate adaptation methodologies.

As part of the above, a *Climate Adaptation Handbook* as well as a series of supporting guidelines have been developed. These are:

- Change Management Guidelines
- Climate Threats and Vulnerability Assessment Guidelines
- Engineering Adaptation Guidelines
- Visual Assessment Manual.

The above documents are available on the ReCAP website as drafts for comments: (http://www.research4cap.org/SitePages/Climate%20Adaptation.aspx).

In addition to these documents, Country Reports have been drafted for Ethiopia, Ghana and Mozambique. It is expected that similar Country Reports will be prepared for the other AfCAP partner countries (DRC, Kenya, Liberia, Malawi, Sierra Leone, South Sudan, Tanzania, Uganda and Zambia) during the proposed Phase 3 of the project, following several in-country engagements with key stakeholders.

Objectives of the Train-the-Trainer Programme (as an initiator)

A one-week train-the-trainer programme has been planned to be held in Ghana to capacitate experienced trainers of the DRC, Liberia and Sierra Leone with the required knowledge to disseminate current best practices on how to deal with the effects of climate change on low-volume rural road networks.

This training will be provided by members of the AfCAP Project Team. It will be based on: (a) the five documents listed above (i.e. Handbook, three Guidelines and the Visual Assessment Manual), supplemented by (b) pre-defined training material to be developed by the nominated trainers of Sierra Leone prior to the course (as a test bed to assess their acumen to act as national trainers; training material to be based on one aspect of one of the documents supplied to them), and complemented by (c) training material supplied by the Project Team during the course.

The training that will be provided by the Project Team will be based on the above five documents through a combination of classroom and in-field training. The end objective is to equip the nominated trainers with all basic information to enable them to replicate the training in Sierra Leone with the aim to (a) create local awareness; (b) instil local knowledge on how to deal with climate effects; and (c) encourage/pursue the embedment of climate effects and climate change in policies, norms/standards and operations, inclusive of decision support systems.

The above training will be reinforced in the proposed Phase 3 of the project. The purpose of Phase 3 would be to involve all AfCAP partner countries as well as AsCAP partner countries with the aim to impart lessons learnt, transfer best practices and embed these in all ReCAP partner countries.

Requirements for the Train-the-Trainer Programme

As the AfCAP National Coordinator for Sierra Leone, we will appreciate it if you could identify and nominate three (3) nationally recognised, experienced and motivated trainees, each strongly motivated towards adaptation for climate change, to participate in the Train-the-Trainers programme as outlined above. Ideally, at least one of the trainees should have deep-rooted experience in training (e.g. academic institutions), but the programme can also accommodate other experienced and industry-acknowledged trainers from either the public or private sector, as long as they are proficient in road engineering and already have a good understanding of the environmental effects of climate on roads.

Dates and venue for the Train-the-Trainers Programme

The five-day Programme will be held from Monday, 01 April 2019 to Friday, 05 April 2019 at the Koforidua Training Centre (KTC) of the Ministry of Roads and Highways, off Nankese-Koforidua Road, Koforidua, Ghana.

The trainees would be expected to arrive in Accra on Sunday, 31 March 2019, and depart either on the Friday night or on the Saturday morning, depending on the availability of flights from and to Sierra Leone.

For more details, please do not hesitate to contact:

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