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

AfCAP Project GEN2014C

Briefing Note No 7: Embedment of Climate Change Aspects in Road Asset Management Systems

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Introduction to the Programme

The African Development Bank (AFDB) states that Africa is one of the most vulnerable regions in the world to the impacts of climate change. The majority of both bottom up and top down studies suggest damages from climate change, relative to population and Gross Domestic Product (GDP), will be higher in Africa than in any other region in the world. In the past four decades (1975 to 2015), African countries have experienced more than 1 400 recorded weather related disasters (meteorological, hydrological and climatological). These disasters have had significant impacts on countries' economies and in particular on rural communities and their livelihoods. The high social vulnerability and low adaptive capacity of these communities as well as their high exposure to natural hazards has resulted in the death of more than 600 000 people (95 per cent due to droughts), left 7.8 million people homeless (99 per cent due to flooding and storms) and affected an estimated 460 million people.

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). In order to help address a significant climate impact to Africa's development, a consortium led by CSIR (South Africa's Council for Scientific and Industrial Research), has been commissioned 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 resilient, future-climate-proof road network that reaches fully into and between rural communities.

Road Asset Management Systems

One of the appropriate adaptation options to deal with the impact of climate change on the road network is to embed climate change risk assessments in road asset management systems. This will support prioritisation and decision-making based on a broader spectrum of attributes, in addition to present road conditions. This will also require road condition assessors to be trained to identify potential climate change related risks and threats within and outside the immediate road environment.

Asset management is thus seen as an overarching business model that provides the framework upon which climate change initiatives can be readily implemented by a road authority.

The Asset Management Process

The International Infrastructure Management Manual (IIMM, 2011) describes the objective of asset management as follows:

"The objective of asset management is to meet a required level of service, in the most cost effective manner, through the management of asset for present and future customers".

A road asset management system therefore needs to consider:

- The policy of the road administration (which in turn should consider government policy);
- Customer needs through defined levels of service for road assets;
- The resources (physical and human), processes and tools required (and available) to monitor and meet these levels of service; and
- Mechanisms for planning for the future and for dealing with unexpected impacts on the road infrastructure.

The asset management process, according to the International Infrastructure Management Manual (IIMM, 2011), is presented in Figure 1.

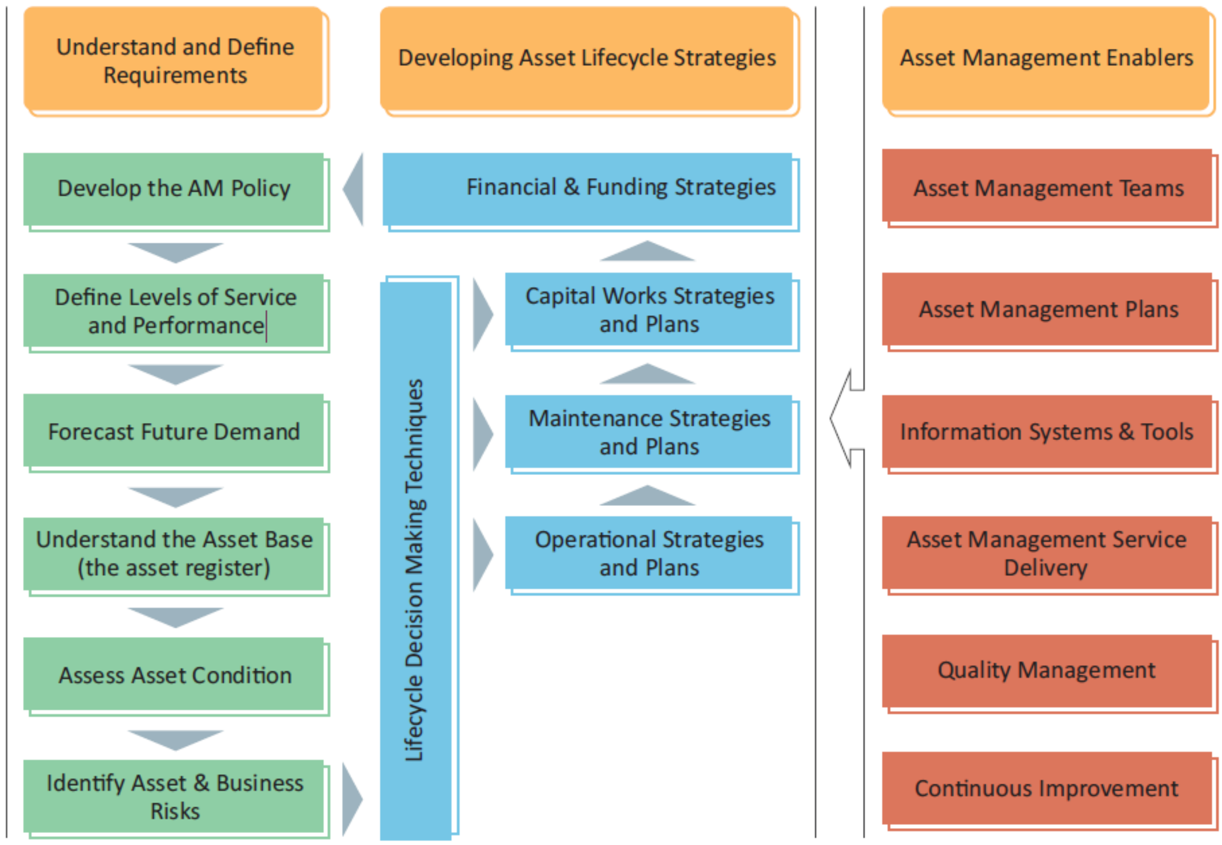

Figure 1: The Asset Management Process (IIMM, 2011)

Recommended Actions to Integrate Climate Change Risk Assessments in the Asset Management Practices

IIMM (2011) defines 17 asset management activities which, when considered together enable holistic asset management. In the World Bank report "Integrating Climate Change into Road Asset Management" published in April 2017, actions are recommended for each of these 17 activities to integrate climate change in asset management practices. The 17 activities and the recommended actions are presented in Table 1.

Table 1: Recommended Actions to Integrate Climate Change in Asset Management Practices (The World Bank, 2017)

Phase	Step	Key Additional Actions
Understand and Define Requirements	Develop the AM Policy	Specifically address climate change within the AM Policy statement, including what horizon is to be planned for
		Have agreements in place on how the damage from major events will be funded and who will be entitled to financial support
	Define levels of service and performance	Ensure network resilience measures (e.g. restore all major roads within 12 hours of end of 1:100 year flood) are included into the level of service framework
		Revise design guides to take into account the changing frequency of climatic events
	Forecast future demand	Future demand forecast such as demographical changes and traffic loading increases should be integrated with climate change impacts on the expected performance of infrastructure
		Providing for future growth in areas of high vulnerability should be avoided
	Understand the asset base	Ensure that data on drainage assets and their vulnerabilities/deficiencies is complete and up-to-date
		All data collection processes should be geospatially referenced
		Road data and information should highlight interdependencies with other infrastructure
		Link life-lines and critical interactions between asset groups in the base data
	Assess asset condition	Data collection should include measuring and recording of specific climatic effects on road network
		Data collection techniques should also include the focus on quantifying the vulnerabilities of pavements to temperature and moisture changes
	Identify asset and business risks	Ensure climate change is recognised as a risk to the asset and delivery of services
		Risk and vulnerability assessments are already commonly used for climate adaptation. These processes should be integrated with risk management from an organisational risk perspective
		The integration with asset management risk in particular promises significant efficiency gains
Developing asset lifecycle strategies	Lifecycle decision making techniques	Road asset management and systems brings a wealth of analytics to the climate adaptation topic area
		Current analyses processes need to incorporate multi objective capabilities
		More emphasis on community involvement in decision making is required when bringing climate adaption into the asset management decision making
	Operational strategies and plans	Operational plans should include specific allowance for identifying and addressing deficient adaptation measures – such as making sure drainage structure are cleaned and without blockages
		Include retrofitting infrastructure that is found to be significantly deficient
		Trial new materials that may better resist climate change
		Operational procedures should include policies and processes identified for responding to disasters

Phase	Step	Key Additional Actions
	Maintenance strategies and plans	Maintenance strategies and plans should include specific allowance and focus on addressing items that limit the impact from climate change
	Capital works strategies and plans	Updating of current design criteria (such as drainage design) is needed to allow for changing rainfall patterns
		New designs should include specific consideration for climate adaptation technologies
	Financial and funding strategies	Financial and funding strategies should investigate the impacts of different investment scenarios into climate adaptation
		Financial and funding strategies should be in place for responding to potential disaster events
Asset management enablers	Asset management team	Effective integration of climate adaptation and asset management must be driven from executive management levels within organisations
		Appoint someone as the climate change champion to drive all these actions through the organisation
	Asset management plans	Ensure that the AMP specifically addresses climate change
	Information management systems and tools	Information management systems should include the recording of specific climatic and impact data for planning purposes
		A data residence plan should be in place to respond to disaster planning needs
	Asset management service delivery/Procurement	Legislation and procurement processes should allow for the response to shock events
	Quality management	Quality management of climate adaptation measures need to ensure its sufficient functioning
	Continuous improvement	Identification of improvements necessary for climate change adaptation

As part of the Economic Growth through Effective Road Asset Management (GEM) project, the guidelines described in IIMM (2011) have been embellished and tailored for rural roads, resulting in only fourteen of the activities considered to be applicable to road asset management systems for rural roads (Geddes, R. et al, 2016). The three activities not included in the GEM project are:

1. Identify asset and business risks;
2. Quality management; and
3. Continuous improvement.

From a climate change point of view, it is important that asset risks resulting from climate events be considered and this activity should therefore be included in the RAMS for rural roads.

The key additional actions described in Table 1 are mostly self-explanatory and relatively straightforward to implement. The following three steps however requires expansion on the proposed key additional items:

- Understand the asset base;
- Assess asset condition; and
- Identify asset and business risks.

These three steps and their required key additional actions are further discussed in this Briefing Note. As part of the description of the additional actions for these three steps, additional climatic and impact data requirements are identified, which thus addresses the following additional action item under the information management systems and tools step:

- Information management systems should include the recording of specific climatic risk assessment data for planning purposes.

Understand the Asset Base

The World Bank report (2017) recommends the following key additional actions in relation to the asset base phase of the asset management process:

1. Ensure that data on drainage assets and their vulnerabilities/deficiencies is complete and up-to-date;
2. All data collection processes should be geospatially referenced;
3. Road data and information should highlight interdependencies with other infrastructure; and
4. Link lifelines and critical interactions between asset groups in the base data.

Items 1 and 2 are expanded on in this section, while items 3 and 4 are not considered relevant to rural roads.

Data Classes in Road Asset Management Systems

Traditionally, RAMS contain two main classes of data, namely Inventory Data and Condition Data. Integrating climate change in Asset Management practices would require additional data items to be recorded and stored in the RAMS database. The additional data items could be classified as either inventory or inspection data, but a better approach would be to include a third class of data in RAMS, namely Climate Change Risk Assessment Data.

Road Network Definition in Road Asset Management Systems

The Road Network definition involves defining the following road network attributes:

- Roads;
- Road Sections;
- Road Links; and
- Road Segments.

The building blocks of a road network are individual roads. A vital component of the Road Network definition is therefore a unique identifier for each road in the network. Rural roads are often divided into sections, each with a new zero km starting point to facilitate management and administration.

Roads and road sections are divided into road links that are uniform in terms of:

- Road type (paved, gravel, earth);
- Road cross-section (road width and paved width);
- Significant changes in pavement construction;
- District or local municipal area in which the road is located;
- Traffic; and
- Topography.

An assessment segment is the length of road for which one visual or instrument assessment rating is recorded. In the case of rural road networks, a road link can be divided into road segments for visual assessment, or alternatively, the entire road can be segmented based on kilometre distance. For urban road networks where road links may be very short, uniform links may be grouped together to form an assessment segment.

Climate Change Risk Assessment data items would also have to be recorded and stored per road link and in many cases per assessment segment.

For road structures, such as bridges, culverts, retaining walls, etc., data items are stored per structure and in many cases, per structure element. For example, bridge condition data is stored at structural element level, such as piers; abutments; decks; etc. The same would apply to Climate Change Risk Assessment data items.

Data on Drainage Assets and their Vulnerabilities/Deficiencies

The vulnerability of drainage structures, such as bridges and culverts would depend on the current capacity of the structure in relation to current climate and environmental conditions and in relation to future climate and environmental conditions. The capacity of the structure is expressed in terms of the return period of the flood for which the structure had been designed. From an economic perspective, the minimum design standard should be based on the return period that corresponds to the design life of the road on which the structure is located. (SANRAL Drainage Manual, 2006) The current return period and future return periods are data items that should be stored as part of the Climate Change Risk Assessment data.

Deficiencies of drainage structures relate to defects on the structure that would make it prone to damage or even collapse in the event of a flood. Defects on structures are identified and rated as part of a visual assessment process. A flood related deficiency index can be calculated using the defect ratings from the visual assessment and specifically defects on structural elements that are vulnerable in the event of floods, such as foundations, embankments, piers, abutments and erosion protection.

Assess Asset Condition

The World Bank report (2017) recommends the following two key additional actions in relation to the asset condition assessment phase of the asset management process:

1. Data collection should include measuring and recording of specific climatic effects on road network; and
2. Data collection techniques should also include the focus on quantifying the vulnerabilities of pavements to temperature and moisture changes.

In this section, the first action is expanded on.

Standard Practise for Road Condition Assessment

While there are several manuals and procedures for road condition assessment, the recommendation in the Economic Growth through Effective Road Asset Management project is that South Africa's TMH12 document be adopted for use as a road condition-monitoring tool. (Geddes, R. et al, 2016(2)). The TMH12 manual is only applicable to gravel roads and has been replaced by TMH9 Standard Visual Assessment Manual (2013), which caters for all types of roads, namely flexible pavements; concrete pavements; block pavements; and unpaved roads (earth and gravel roads). It is recommended that the TMH9 document rather be adopted for use of road condition monitoring tool.

The Standard Visual Assessment Manual provides guidelines for assessing the condition and performance of roads (focussing on earth, gravel and bituminous sealed roads) for use in management systems and maintenance programming.

Visual assessments on any road can be used to:

- Determine Visual Condition Indices;
- Maintenance and rehabilitation needs; and
- Prioritise projects in a decision support system.

Unsealed roads (both earth and gravel), in particular, are highly dynamic systems with the appearance and condition varying almost from day to day and for routine use the visual assessment is most applicable for determining:

- Whether the road could still be effectively maintained with a motor grader;
- Scheduled maintenance requirements in the form of:
  - Regravelling;
  - Reshaping; or
  - Spot gravelling; and
- Whether the gravel on the road is suitable for the traffic and environment and what type of distress is typical of the road/gravel combination.

Paved roads on the other hand generally deteriorate slower with a continual, almost uniform deterioration before an acceleration in defects prior to a road failing.

The visual assessment process involves the identification and description of the quality of materials on the road (for unpaved roads) and the typical distresses that affect the specific type of road. The distresses are described by recording their main characteristics – the so-called attributes of distress. The attributes of distresses are the type of distress, the degree of the distress; and the extent of the distress.

The visual assessment data collected can be used for determining various indices (e.g. Visual Condition Index (VCI)). The data collected can also be used:

- As a basis for predicting maintenance requirements;
- For prioritising maintenance actions (e.g. defects with a severity of 4 or 5 should ideally be given immediate attention, while defects with a severity of three should be considered as a warning that will require attention in the near future);
- For monitoring improvement or deterioration in the overall road network as a result of funding fluctuations;
- For direct comparisons of the performance of various roads;
- For location of specific problems; and
- As a basis for project level investigations.

Measuring and Recording of Specific Climatic Effects on the Road Network

Currently, for road management, maintenance, and rehabilitation planning purposes, visual condition assessments of a road network are usually routinely carried out at specified frequencies. These normally look at the road condition, classifying distresses such as cracking, deformation, rutting, potholing, etc. by degree and extent to prioritise and budget for follow-up management operations. Generally, only the road carriageway area is assessed. Similar assessments for Bridge Management Systems are also carried out in certain countries, and these are mostly related to the planning and management of maintenance and repairs of structures (including bridges and culverts). It is, however, necessary to add to this information to provide the required inputs for climate change risk assessments and the implementation of appropriate adaptation techniques to improve the climate resilience of the infrastructure.

Problems specifically related to climatic effects that must be identified and described by way of a visual assessment process include the following:

- Erosion potential;
- Subgrade material problems;
- Drainage efficiency in the road reserve;
- Drainage from outside the road reserve;

- Slope stability;
- Construction quality; and
- Maintenance effectiveness.

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

The following distresses relating to climatic effect should be identified and rated during a visual assessment process:

- Erodibility
  - Sugbrade
  - Road surface - unpaved
  - Side drains - unlined
  - Embankment slopes
  - Cut slopes
- Subgrade problems
  - Material type
  - Moisture
- Drainage (in reserve)
  - Road shape
  - Shoulders
  - Side slopes
  - Side drains
  - Mitre drains
- Drainage (streams)
  - Structure
  - Approach fills
  - Erosion of approach fills
  - Protection works
  - Flood plain
- Slope stability
  - Cut stability
  - Fill stability
- Construction
  - Overall finish
  - Erosion protection works
- Maintenance
  - Quantity
  - Quality

During the visual assessment process, these distresses are rated in terms of degree and extent. The degree of a particular type of distress is a measure of its severity. The general descriptions of degree of each type of distress are presented in Table 2.

Table 2: General description of the Degree classification of distresses

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

(Source: Paige-Green & Verhaeghe, 2018)

The extent of any distress is a measure of how widespread the distress is over the length of the road segment. The general descriptions of extent of each type of distress are presented in

Table 3: General description of the Extent classification of a distress

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

(Source: Paige-Green & Verhaeghe, 2018)

For prioritisation purposes, the degree and extent ratings for each distress per road section is combined to arrive at a distress score. All the distress scores for a road section are then combined to arrive at what can be called a Climate Change Priority Index.

Slope Management System

Where appropriate, it is advisable to include, as part of the Asset Management System of all road authorities, a basic *Slope Management System* (SMS) that identifies the potential for failure and consequences of failure of all slopes within their jurisdiction. A SMS should make provision for both rock and soil slopes and must contain rating methodologies to rate various characteristics of slopes.

The following are examples of such characteristics that should be rated (Leylandt, R. 2010):

Slope character parameters:

- Slope height
- Slope failure frequency
- Average slope angle score
- Launching features
- Ditch catchment

Climatic conditions:

- Annual precipitation
- Seepage/water
- Aspect
- Sedimentary rock slope geological conditions
- Degree of undercutting
- Jar slake
- Degree of inter-bedding

Crystalline rock slope geological conditions:

- Rock character
- Degree of overhang
- Weathering grade

Discontinuities:

- Block size/volume
- Number of joint sets
- Continuity and dip
- Aperture
- Weathering
- Surface texture

Block in Matrix slope geological conditions:

- Block size
- Block shape
- Vegetation

Soil slope geological conditions:

- Block size
- Tension crack
- Structures/bedding

Economic factors:

- Traffic
- Length of detours
- Class of detours

Climate change would obviously influence the climatic conditions and the rating methodologies for these characteristics should take into account predicted changes in annual precipitation and changes in seepage potential.

Identify asset and business risks

The World Bank report (2017) recommends that climate change must be recognised as a risk to the asset and delivery of services. It furthers states that risk and vulnerability assessments are already commonly used for climate adaptation and these processes should be integrated with risk management from an organisational risk perspective.

The recommended way to incorporate climate change as a risk in the asset management system is by way of the District-level Climate Risk Screening, as described in the report "Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa - Climate Threats and Vulnerability Assessment Guidelines" (Le Roux, A et al, 2017).

At district level, the analysis of climate threat data leads to the categorization of districts in terms of being impacted by historical climate threats, e.g. by aggregating the number of climate threat events, such as severe flooding events in past four decades, per district. The number of climate threat events per district can then be imported into the road asset management system as an attribute for each road in the particular district, e.g. a Severe Flood Index. This index can then be used in the RAMS in conjunction with other indices, such as the VCI, when calculations are done to prioritise roads in terms of maintenance or adaptation needs.

More importantly, these district level climate change risk indices can be used to prioritise districts for measuring and recording specific climatic effects on the road network in these high priority districts. As previously described, these distresses are rated in terms of the degree and extent and these ratings are used to arrive at what can be called a climate change priority index for each road section. The climate change priority index is an indication of the climate change risk to the asset, which can then be used in the RAMS in conjunction with other indices, when calculations are done to prioritise roads in terms of maintenance or adaptation needs.

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