



# Climate Vulnerability Assessment Summary Report

June 2020



Project funded by Nordic Development Fund  
and implemented by NTU International A/S



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## Foreword

This document summarises a Climate Vulnerability Assessment (CVA) Report completed by NTU International in 2018 as part of the Nordic Development Fund-financed Development of Climate Resilient Infrastructure Standards and Codes Project in Zambia. Key contributions to the formulation of this CVA came from an extensive process of consultation and discussion within the sector without which the outcome would have been less effective. Those contributors are all thanked for their valuable inputs, not least the Road Development Agency which supervises this Project.

The NTU CVA team included: Jenny Clover, Roberto Durero, John Murphy, Chris Mpande, Chabala Chiyaze, Joseph Sichone, David Ngwenyama and Mebeelo Kafungwa. The CVA Report and this Summary Report were edited by Adam Pope and Adilson Vilinga.

This document is a precis of the full CVA report. All the key issues are discussed but some of the material is rearranged to improve the flow of the narrative. Some new material is included to take account of the rapid developments in the climate agenda in Zambia and internationally.

This report was completed before the COVID-19 pandemic started with its associated dramatic reductions in greenhouse gas emissions and air pollution levels – and presumably climate effects. Those effects were noticed very soon after shut-down responses to the pandemic were instituted. A clear indication of what mankind can achieve to reduce climate change - if the will exists.

## 1. Introduction

The warming of our planet and the associated effects on climate characteristics is one of the most pressing issues facing the Earth, its inhabitants and its ecosystems. Climate change related policies and actions are gathering momentum in Zambia as well as internationally, amongst public and civil society organisations, in urban and rural societies and in all age groups.

Previously, international focus has been on climate change mitigation measures that today are considered by many to be 'too little, too late'. Consequently, there is now increasing support for parallel, climate change adaptation initiatives that can address both the inevitable downsides of long running political indecision, as well as the critical immediate issues. It is now widely agreed that any climate change strategy must include both mitigation measures and climate change adaptation initiatives.

This Summary Report focuses on a small sub-set of the global climate discussion: examining Climate Vulnerability Assessment as a tool that can be used to address climate impact mitigation and to strengthen climate change adaptation and resilience in Zambia's road sector.

### 1.1 Definition of terms

An important starting point for any discussion about the climate vulnerability of road transport infrastructure in Zambia is ensuring that there is a common understanding of key issues and terms. For example, there is considerable confusion about the difference between climate and weather and separating these terms is important.

**Climate** is defined by atmospheric characteristics derived from long-term average data sets for a variety of climate phenomena – temperature, humidity, precipitation (rainfall or snow), evaporation, sunlight hours, air pressure. In short, a climate is the usual, long-term pattern of atmospheric conditions in a given region or location.

**Weather** in contrast, describes current atmospheric conditions and near-instantaneous events resulting from the interplay of atmospheric processes. Examples of weather are current temperatures and winds, or events such as cyclones, tornadoes, air masses and fronts, winds, snow storms and so on.

As some still reject the notion that climate change has a strong link to human (anthropogenic) influence, then of equal importance is separating the definitions of climate variability and climate change.

**Climate variability** is the outcome of minor changes in the usual pattern of climatic cycles. This might be the result of local changes in normal seasonal factors related to the relative angle of the Sun to the Earth and the associated hemispheric pressure systems and jet streams. Alternatively, it may be due to changes in the general circulation of the lower atmosphere resulting from changes in the extent and magnitude of natural surface land

and sea surface temperatures – as an example the latter causes the El Niño/La Niña phenomena that impact on patterns of rainfall in southern Africa and elsewhere.

**Climate change** in contrast is a sustained modification to climate characteristics caused by changes in the heat balance of the earth – the balance between incoming solar energy and outgoing and reflected energy, exacerbated by the additional greenhouse effect that is established through additional human-generated greenhouse gas (GHG) emissions (Figure 1). As an example of climate change, Zambia follows most of the world in having experienced a steady increase in average surface temperatures over the last 50 to 60 years of records.

Weather, climate variability and climate change describe conditions over different timeframes: generally, weather is over hours, days and months; climate variability is over months, years and decades; and climate change is over decades and centuries.

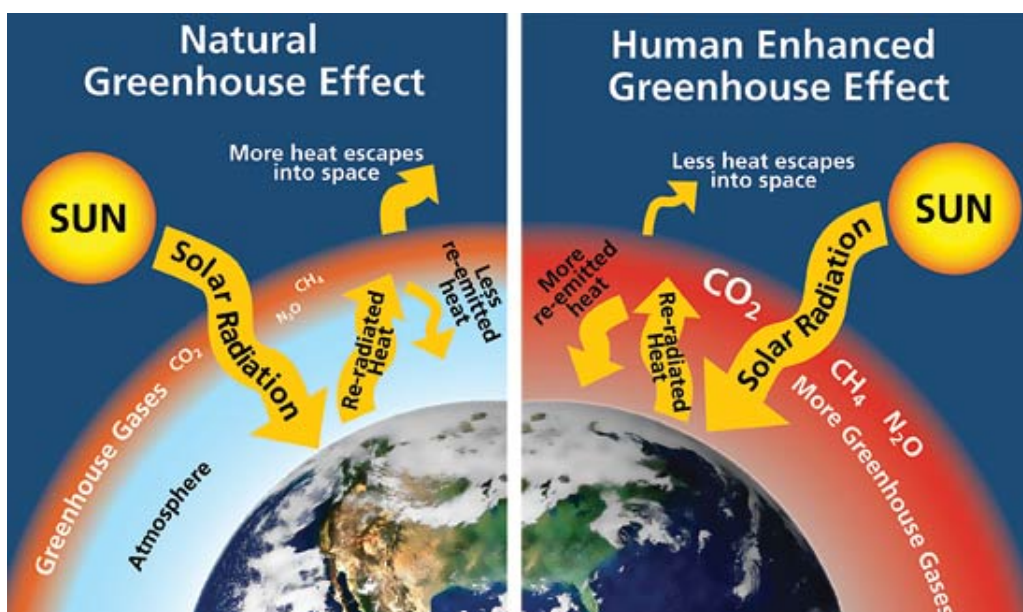
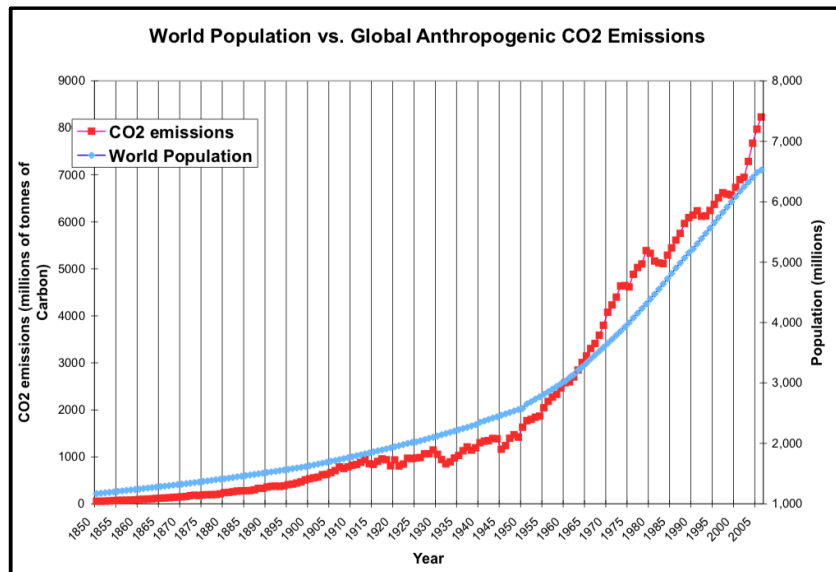


Figure 1: Global heat balance and the greenhouse effect

Source: NOAA, 2018

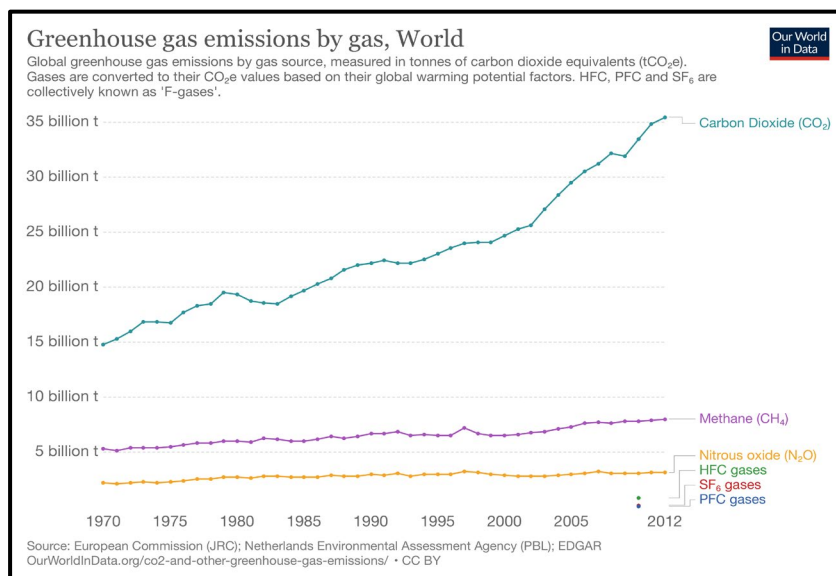
The two graphs Figure 2 and 3 present some pertinent climate-related trends. Figure 2 illustrates the close similarity of trends in global population and in carbon dioxide (CO<sub>2</sub>) emissions to 2005, indicating a plausible link between people and their individual and collective carbon footprints (although CO<sub>2</sub> trends have escalated since 2010). This suggests that the forbidden subject of population growth should be part of the narrative to reverse global warming trends.



**Figure 2: Trends in global population growth and carbon dioxide emissions – 1850 to 2005**

Source: <https://www.easterbrook.ca/steve/2009/06/population-growth-vs-emissions-growth/>

Figure 3 shows the steady or exponential increases in emissions of human-influenced greenhouse gases (GHG) including methane [CH<sub>4</sub>], and nitrous oxides [NO<sub>x</sub>], that currently form smaller proportions of total GHG emissions but have higher inherent levels of climate impact.

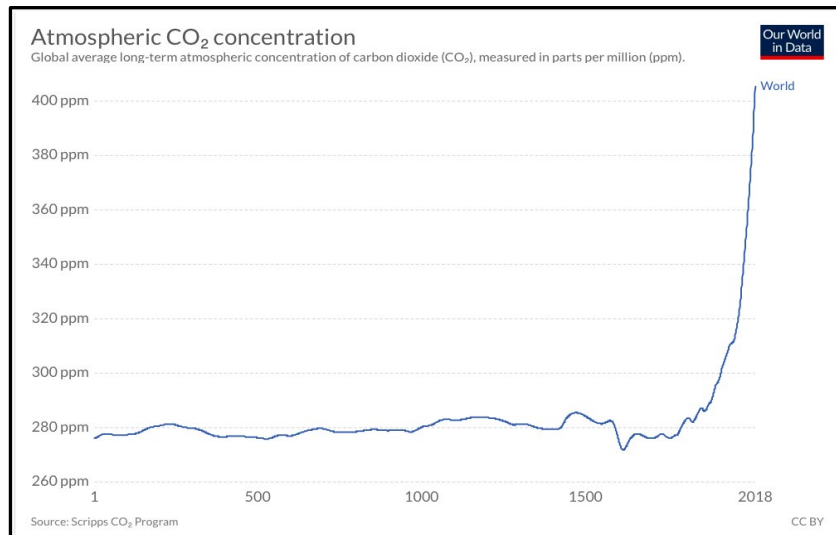


**Figure 3: Trends in global greenhouse gas emissions – 1970 to 2012**

Source: Hannah Ritchie and Max Roser (2019) - "CO<sub>2</sub> and Greenhouse Gas Emissions". Published online at [OurWorldInData.org](https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions). Retrieved from: '<https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions>' [Online Resource]



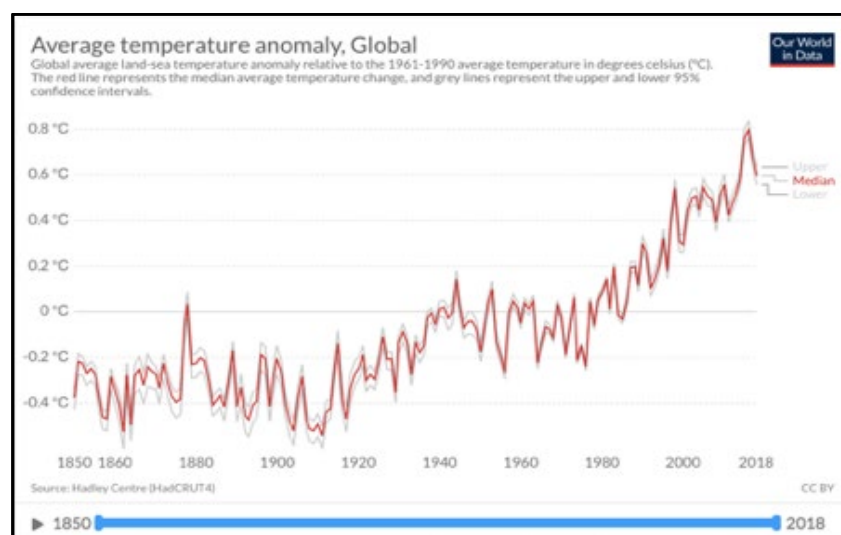
If further evidence for concern is needed, Figure 4 shows the trend in CO<sub>2</sub> atmospheric concentrations over the last 2000 years and particularly since the industrial age. It emphasises the strong coincidence of increasing populations and industrialisation and of greenhouse gas emissions.



**Figure 4: Trends in atmospheric carbon dioxide concentrations since 1AD**

Source: <https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions>

There are now strong positive correlations between exponential increases in carbon dioxide, methane and other GHG emissions in the atmosphere, and increases in average surface temperatures (known as ‘global warming’). Global warming is now having very visible effects in reducing the polar icecaps, polar and continental glaciers, increasing melting in the high latitude permafrost zones and catastrophic fires, even in high latitude boreal forests. Figure 5 illustrates the trend in global warming with rapid increases from the beginning of the 20<sup>th</sup> century and further acceleration from 1980.



**Figure 5: Trends in global mean surface temperatures 1850 to 2018**

Source: Hannah Richie and Max Moser, 2018: *CO<sub>2</sub> and other Greenhouse Gas Emissions*, Global Change Lab, University of Oxford.

Global warming is impacting widely on terrestrial and marine ecosystems, agricultural systems, urban landscapes and on urban and rural infrastructure across the globe. These impacts and the accumulating volume of climate research data and findings are now encouraging policy makers to give climate change and the impacts of climate change due attention. Funds are becoming available for mitigation and adaptation measures, with the realisation that there is a significant lag between achieving a reduction in GHG emissions and a reduction in global temperatures and associated climate impacts.

## 1.2 Climate change and variability and current issues

Ten years ago, the climate debate was highly polarised between “deniers” and supporters of climate change - in spite of good evidence from a wide range of global greenhouse gas (GHG) and surface temperature trends - the so-called “hockey stick” studies.<sup>1</sup> Recent 2019 reports have endorsed earlier work linking surface temperature rises and increases in greenhouse gases.

These new studies (Figure 6) show clearly:

- that atmospheric CO<sub>2</sub> concentrations are higher now than at any time in the last 2000 years;
- that for 98% of the Earth, the warmest period in the last 2,000 years was in the last century;
- this warming period is now affecting the whole planet at the same time for the first time; and
- the speed of global warming has never been as high as it is today.

Responses to this evidence were slow initially. However, the 2015 Paris Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change did agree the objective of limiting the rise of average surface temperature to 2.0°C above pre-industrial levels with the aim of restricting the increase to 1.5°C if at all possible.

Today there is near-universal acceptance that climate conditions are changing worldwide, and that human influence is a key driver. It is accepted that addressing climate change requires a holistic approach that includes physical measures and behavioural change. We witness increasing public frustration at the relatively slow response made by many governments since the 2015 Paris summit and at subsequent meetings. Civil society campaigns such as the 2019 Thunberg-inspired school children’s protests and the ‘Extinction Rebellion’, both still very active, are examples.

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<sup>1</sup> E.g. Mann, Michael E.; Bradley, Raymond S.; Hughes, Malcolm K. (23 April 1998), "Global-scale temperature patterns and climate forcing over the past six centuries" (PDF), *Nature*, **392** (6678): 779–787



Figure 6: The recent IPCC Synthesis and Global Warming of 1.5°C reports

### 1.3 Why are climate and weather effects important to global economies and to Zambia?

Climate-related impacts are becoming an increasingly tangible barrier to maintaining global economic growth and to achieving the internationally subscribed Sustainable Development Goals (SDG). In a Zambian context these impacts are now recognised also to be a significant factor detracting from national development targets (Figure 7).



Figure 7: Climate and weather-induced damage to road infrastructure

Source: RDA Zambia – Kafue-Chirundu Road (T2)

Climate change and variability threaten people's livelihoods. Generally, the biodiversity and other ecosystem service mechanisms that sustain human life are adversely affected. At a location-specific level, livelihoods are negatively impacted by climate-related damage to roads and other vital economic infrastructure. Transport networks are vital for national economic performance. We have already witnessed the effects of climate change on supply-based sectors such as agriculture, fisheries, forestry and tourism, all of which are important to livelihoods at every level.

Agriculture, for example, requires both new agronomic approaches (such as short season crop varieties), climate-resilient agricultural systems, improved land use planning and downscaling livestock production to minimise the impacts of extreme wet and dry conditions and to reduce GHG emissions. Tourism, another example, is affected by the impact of climate change on biodiversity, landscapes and ecosystems, such as forests, rivers, waterfalls, and on species' survival, upon which livelihoods and wellbeing depend.

## 1.4 Historical climate and weather trends in Zambia

Studies by the Zambia Meteorological Department (ZMD) and the University of Zambia (UNZA) on historical trends in climate data in Zambia for the last 60 years (1950-2013) indicate that climate variability and change has been a reality for some time. However, that change has not been uniform. Key findings are:

- 1) The temperature of the warmest day is increasing per year across the country. The mean annual temperature has increased by 1.3°C since 1960, an average rate of 0.29°C per decade. No definitive data yet exist to show whether this trend is accelerating, stable, or now declining but on-going work suggests a continuing growth in surface temperatures.
- 2) The annual count of hot spells is increasing for the entire country. The average number of hot days (when temperatures are above 35°C)<sup>2</sup> and nights per year increased by 12% between 1960 and 2003 and is projected to continue to grow.
- 3) There is an increasing trend in maximum one-day rainfall events in a year for much of the country. However, the (hotter and dryer) western and southern parts are experiencing a decreasing trend. This suggests that intense storms will become a common feature over much of the country.
- 4) There is generally a decreasing trend across the whole country for the maximum total rainfall in five consecutive days exceeding 100 mm. However, there are specific areas in agro-ecological region III (the higher rainfall region) that indicate an increasing trend in maximum total rainfall in five consecutive days.
- 5) Rainfall seasons, especially in southern Zambia, are becoming less predictable and shorter (most notably in the south-western area), with more rainfall falling in the

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<sup>2</sup> The temperature threshold for a 'hot day' in any region or season is defined by the daily maximum temperature (TX) which is exceeded on the 10% warmest of days in the standard climate period (1970-99). The TX90p index is then defined as the frequency with which daily maximum temperature exceeds this threshold in any month, season or year.

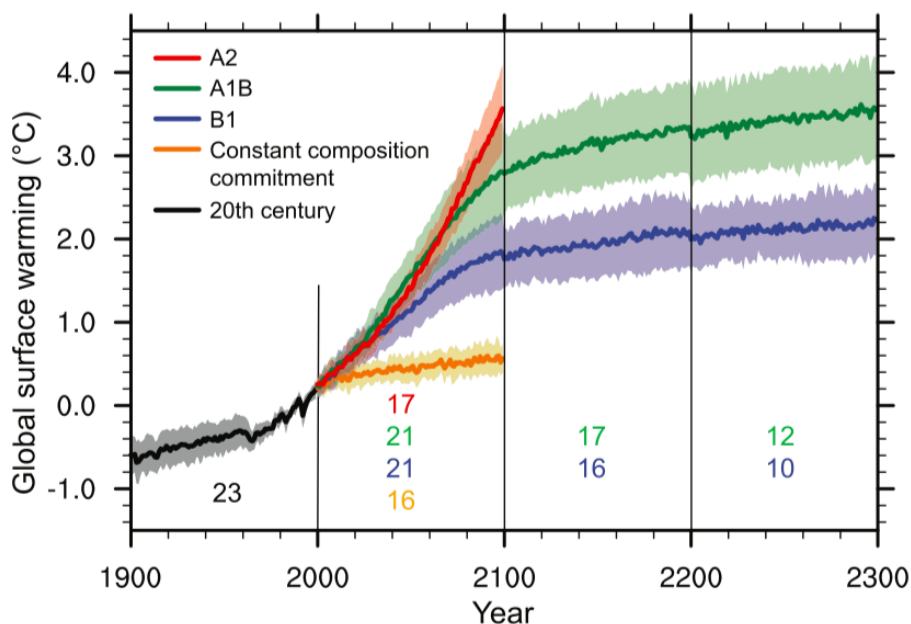
months December, January and February and in fewer, more intense events, often with large dry gaps.

- 6) The trend in contribution to annual total rainfall from very wet days, is positive across most of the country, the exception being the south-western parts of the country. However, the overall trend suggests a gradual fall in mean annual rainfall.

## 1.5 Future climate trends for Zambia

Given recent climate trends in Zambia and globally there is growing importance in developing a sound understanding of what future climate characteristics might be. Zambia has experienced a number of anomalous climate related events and cycles in the past, including extreme temperatures, droughts and dry spells, and seasonal and flash floods. These have often been correlated with periodic El Niño and La Niña conditions. The frequency of these extreme events, however, has increased in recent years, partly uncorrelated with El Niño/La Niña events and the trend is expected to continue. The country can now expect with a high probability that at least one agro-ecological zone will experience abnormal weather events in any given year.

Clear patterns in historical trends and a number of forward-looking projections, including the widely-used Coupled Model Inter-comparison Project, Phase 5 (CMIP5) models included in the IPCC's Fifth Assessment Report (AR5), indicate that average surface temperatures are increasing steadily. The mean annual temperature is now projected to increase by about 0.3°C per decade to the 2060s, to between at least 1.2°C and possibly exceeding 3.4°C above pre-industrial levels. Current global temperature trends support the higher scenario figure (Figure 8) and emphasise the future temperature impacts likely to be faced by road infrastructure, exacerbated by projected increase in hot day by up to 29% and hot nights by up to 54% by 2060.



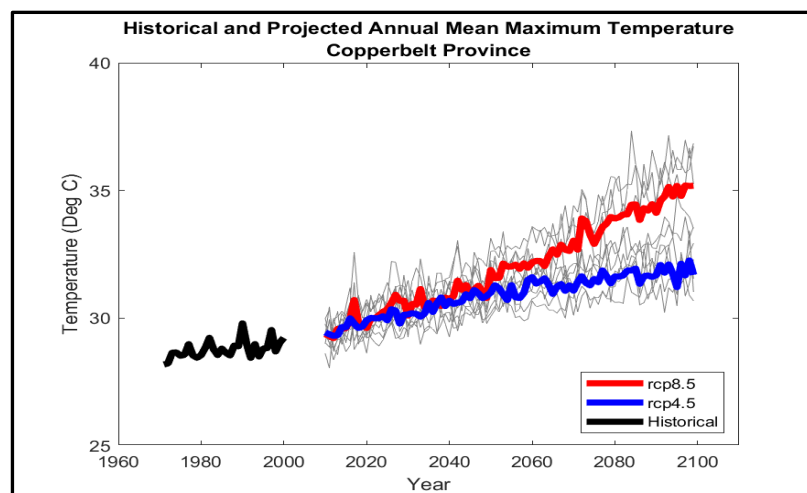
**Figure 8: IPCC Projected Temperature Scenario for 2100 and 2300**

Source: IPCC, 2007

In Zambia, the projected rate of warming is a little more rapid in the southern and western regions of Zambia than the northern and eastern regions. The western part of the country is also likely to become generally drier, with marked temperature increases projected under low mitigation modelling scenarios.

Projections for rainfall vary from model to model and scenario, though most models predict a decrease in the annual precipitation across Zambia. Rainfall seasons in southern Zambia have already become less predictable and shorter (most notably in the south-western area) with rainfall falling in few more intense events. Importantly, most models predict an increase in the frequency and intensity of extreme precipitation events during the rainy season, with a greater likelihood of flash floods. In the north-east, increases in both mean rainfall and extreme rainfall events are likely.

More recent work by the ZMD has been downscaling global climate models for Zambian conditions. These results also suggests that while average surface temperature trends are consistently increasing, rainfall trends are much less consistent. Figures 9 and 10 demonstrates the historical trends and projections to the turn of the century for surface temperature and rainfall, respectively, for Copperbelt Province.

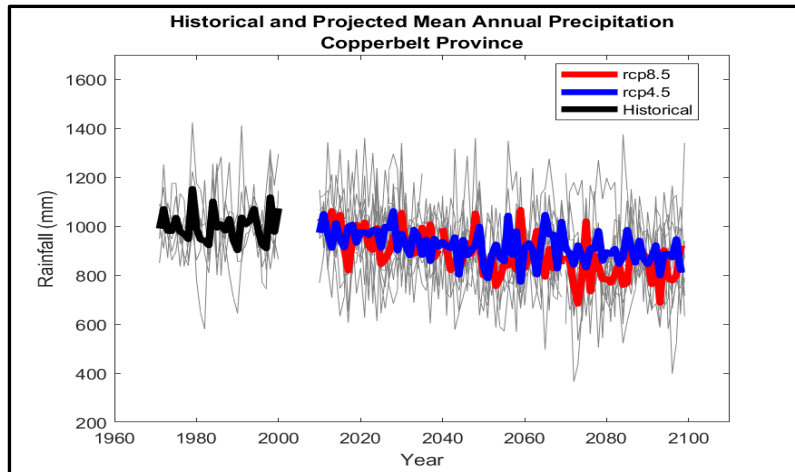


**Figure 9: Temperature trends in Zambia's Copperbelt Province, 1960 to 2100**

Source: *Zambia Meteorological Department, 2019*

It is noteworthy that an average of the upper and lower climate projections still suggests average surface temperatures increasing by more than 2°C by 2100.

Somewhat in contradiction to previous global estimates, both the recent ZMD projections for the Copperbelt Province show a reduction in mean annual rainfall by approximately 100 mm per year by 2100. However, annual variability is moderately high.



**Figure 10: Rainfall trends in Zambia's Copperbelt Province 1960 to 2100**

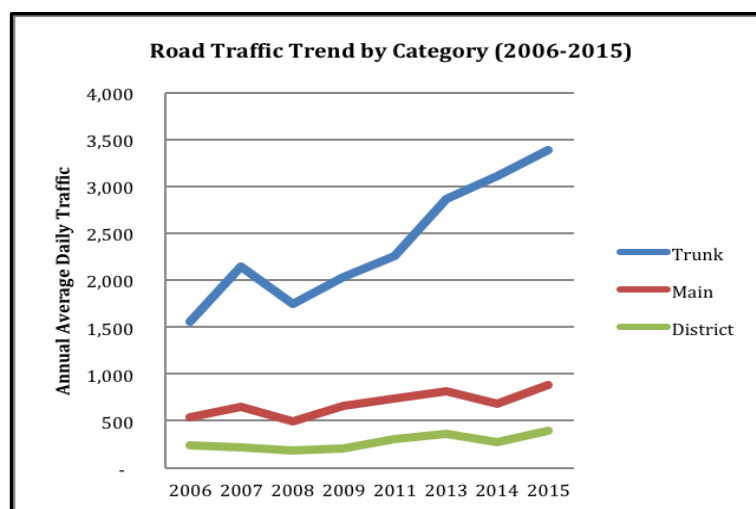
Source: Zambia Meteorological Department, 2019

In addition to other sources of Zambian climate information, the World Bank Climate Knowledge Portal maintains useful set of climate variables and projections and impact predictions - <https://climateknowledgeportal.worldbank.org>.

## 1.6 Key climate challenges for Zambia's road sector

Zambia is at crucial point in its economic development. Industrial activity, mainly in the form of mining (the current principal driver of growth), together with agricultural production and construction, has continued to grow countrywide in the last decade. More recently, tourism is increasingly important and provides much needed diversity to economic growth sector.

Zambia's transport systems are essential to these sectors and to the value chains of the different products involved but are under strain. The under-performance of the rail sector has resulted in increasing pressure on the trunk road network, with accelerating traffic levels and freight loads (Figure 10) which should be accommodated by rail.



**Figure 11: Road traffic trends by category (2006-2015)**

Source: Road Development Agency, 2018

Economic growth is being stifled by overloaded road networks, increasing traffic congestion and delays. These issues are also climate-related as they contribute to global warming through unnecessary vehicle exhaust and particulate emissions and hydrocarbon consumption. They are, therefore, important within a holistic national approach to mitigating and adapting to climate change and variability.

Precipitation- and temperature-related impacts include destruction of road pavements and bridges, followed by a plethora of associated indirect impacts: interruption of the delivery of goods and services to the market, increase costs of delivery, increased consumption of fuels and vehicle operating costs, and construction and maintenance requirements. These factors all contribute to a negative climate feedback loop driven by increased carbon dioxide and nitrous oxide gas (GHG) emissions and thus to additional costs to the economy.

Managing climate resilient road and inter-modal infrastructure must take cognisance of two distinct forms of climatic change that will both impact on the long-term performance of Zambia's road infrastructure:

- slow changing climate trends, such as gradually increasing temperatures and higher rainfall, or intensity of rainfall and/or longer drought periods; and
- extreme climatic events that have more immediate and direct impacts and may result in major interruption to sections of the road network unless addressed.

Mitigating and adapting to these two impact forms require different approaches, combined within a unified climate resilience strategy.

## **1.7 Planning improved climate resilience for Zambia's road sector**

Climate variability and change are recognised by planners to be increasingly costly variables affecting the Zambian economy and require improved data collection and analysis. The 7NDP and the transport sector planning documents, such as the National Transport Master Plan (NTMP), recognise the increased importance of being able to make informed and cost-effective decisions that will secure a climate resilient road transport sector for Zambia.

We have noted above that climate trends, weather events and associated hydrological data are available in Zambia from observations over the last fifty years but the processes and information availability require strengthening. Projected future trends are also becoming more defined and statistically significant. We can use this accumulated information to examine more closely the challenges that climate factors present to the road transport sector and to plan for improving climate resilience in the road network.

We used a tool called the Climate Vulnerability Assessment (CVA), discussed in the next chapter. The CVA tool provides a mechanism to test and map detailed source data, institutional capacity, and other climate-related strengths and weaknesses in the road sector.



## 2. Climate Vulnerability Assessment and Zambia's Road Network

### 2.1 The relevance of climate vulnerability

Climate impacts on road infrastructure have occurred and are expected within the normal range of climate and weather patterns:

- a) because society cannot afford to prepare for all possible eventualities; and
- b) in any case individual events are sometimes outside our knowledge base.

But exacerbating these risks, the normal range of climate characteristics are now changing because of global warming influences. Consequently, establishing the potential vulnerability of road systems and other infrastructure to these longer-term changes is becoming increasingly important as the associated impact risks rise.

Achieving useful CVAs under stable conditions is relatively straightforward. However, success is more difficult and complex in situations of uncertainty. The trajectories of temperatures, humidity, rainfall and other atmospheric phenomena are increasingly difficult to predict, even with our best global and downscaled climate models. So, establishing valid estimates of sensitivity, exposure and adaptive capacity face challenges.

Climate Vulnerability Assessment is used around the world to help design investments in a wide range of sectors from agriculture to tourism and engineering infrastructure. The relevance of CVA and the associated calculation of risks to the road sector is useful for asset investment planning and management processes, and will assist in key decision-making issues related to:

- ***The protection of critical transport links***  
With adequate climate information priority can be given to highest risk/most vulnerable road links in order to ensure these routes are able to withstand expected high temperature, storm, flood, or other weather events, or climate trends, so as to protect the most critical road links.
- ***Informing sectoral and strategic planning***  
CVA identifies transport corridors, inter-modal sites and development hubs where application of climate resilience expenditure will accrue the largest economic benefits, particularly in conditions where resources are very limited.
- ***Identifying potential areas for resilient technologies***  
Areas that have in the past suffered patterns of climate and weather-related damage areas can be identified, where climate resilience applications will have the greatest benefit.
- ***Retrofitting infrastructure***  
The application of incremental knowledge of climate-related stressors and responses can be used to define and attend to transport sites and links where climate resilience is notably deficient.
- ***Preventing over-capitalisation***  
When it is apparent that a road link is exposed to near certain risk of flooding, or other climatic impact within a given return period, maintenance planning can be

adjusted to optimise maintenance levels to avoid over-capitalisation (that may be lost in an extreme event).

## 2.2 The application of CVA

Climate impacts on road infrastructure are expected within the normal range of climate and weather patterns. The previous section showed that the “normal” range of climate characteristics are changing and that we need to assess the potential vulnerability of road systems and other infrastructure to the longer-term changing “normal”. Climate Vulnerability Assessment (CVA) measures the possible impacts of climate and weather events on people and infrastructure (both positive or negative).

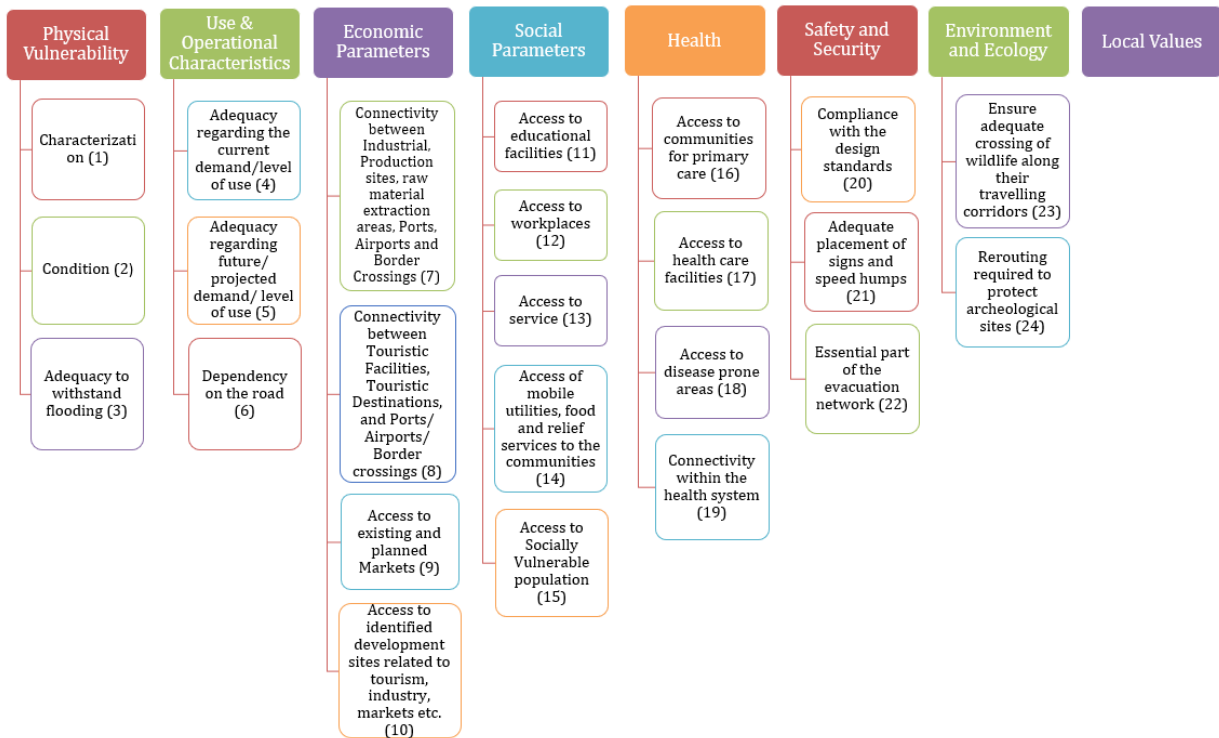
The CVA tool:

- 1) Assesses the **criticality** of the various elements of the system that may be affected. (The system may be national, an economic sector (in our case a road transport network), an individual project, or location).
- 2) Assesses the system according to three criteria: **sensitivity**, **exposure** and the **adaptive capacity**.
- 3) Based on the context of the criticality and the three criteria, CVA establishes the system’s **climate vulnerability**.

Using the CVA tool is straightforward under stable conditions. But it is more difficult and complex in situations of uncertainty and change. The current trajectories of temperatures, humidity, rainfall and other atmospheric phenomena are difficult to predict, even with our best global and downscaled climate models. It is challenging to establish valid estimates of **sensitivity**, **exposure** and **adaptive capacity**.

Before we proceed to examine the process involved in CVA in detail, clarity on some key terms is important and they are shown below.

<b>Hazard:</b>	A physical process or hydro-meteorological event or phenomena that can harm human health, livelihoods, or natural resources.
<b>Critically:</b>	A term that defines how critical an asset is to that system. Values are often established through a multi-criteria analysis (MCA) methodology (Figure 12).
<b>Sensitivity:</b>	Is a measure of how a system may be affected by, or respond to, climate stimuli; for example, how a crop will respond to a changed rainfall regime.
<b>Exposure:</b>	Describes the details of a system’s configuration that may inherently increase, or decrease the magnitude of its response to climate stimuli. For example, a road network through a low altitude, tropical valley may have a high exposure to increasing extreme temperatures and increasing drought cycles.
<b>Adaptive Capacity:</b>	The ability of a system to absorb, or respond to, a climate stimulus.
<b>Vulnerability:</b>	This measures the overall susceptibility of a system to changing climate circumstances and weather events as a function of its exposure, sensitivity and adaptive capacity.

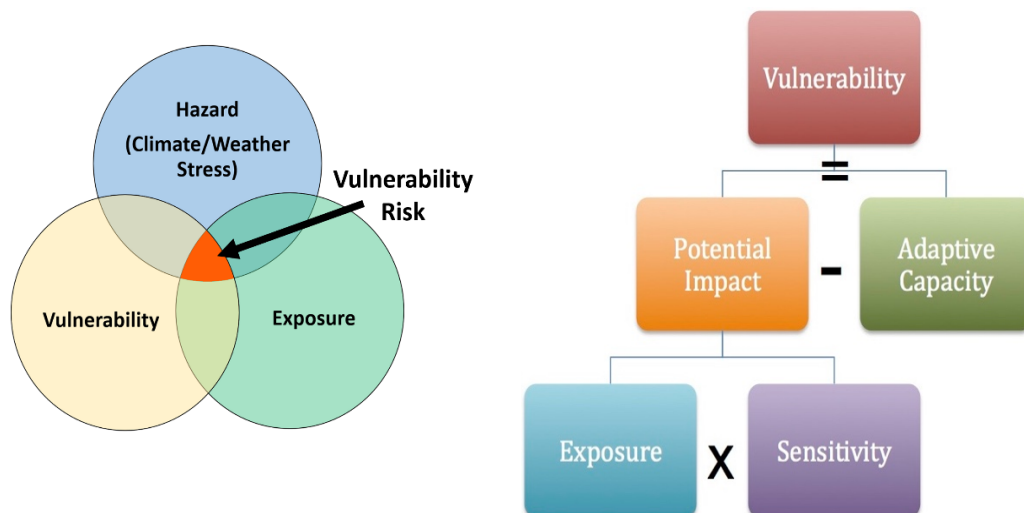


**Figure 12: Example of a Multi-Criteria Analysis Used by the World Bank for Belize**  
 Source: World Bank, *Prioritizing Climate Resilient Transport Investments in a Data-Scarce Environment*

The area of overlap between the stressor (hazard), exposure and sensitivity determine the level of vulnerability risk associated with that particular hazard within a defined criticality framework. A further consideration then, is the adaptive capacity of a system – how well it can adapt to changing circumstances (Figure 13).

A clear understanding of the detailed dynamics of relevant systems is then an important pre-requisite to a useful climate vulnerability assessment. These should include:

- **System dynamics** - an in-depth understanding of the nature of the changing environment (characterisations of future climatic, weather and other environmental and socio-economic conditions: where these occur and how fast they are changing);
- **Spatial factors** - understanding the potential impact and extent of impacts on the infrastructure in as much detail as possible; and
- **Timeframe** - having an estimated time frame for changes taking place and/or the probability and return period of hazard events.



**Figure 13: The interactions between stressors, exposure and sensitivity, adaptive capacity and overall vulnerability**

### 2.3 Modelling climate vulnerability assessment

CVA models vary according to each unique situation (e.g. small islands are particularly prone to the effects of rising sea levels, while mountainous areas are more impacted by rainfall-runoff conditions and landslides). We focus here only on Zambia’s road transport network, and ask the same core questions:

***What are the climate parameters relevant to the situation?***

There are increasing volumes of global and national climate data for CVA applications. Local area specific climate data for specific road sectors or catchment is still a constraint but researching and then choosing the most appropriate data sources is an important first step. Available local knowledge can be of great help in a scarce data environment.

***Are there any discerned changes in climate or weather patterns?***

The ZMD is providing an increasing array of local climate trend data as well as projections through to the end of the century. These are now available at the provincial level, supplementing and increasing the accuracy of national and global projections. These, and earlier analyses all show that there are measurable changes in climate.

***Are there any geographical or climate factors that are pertinent to the situation?***

Zambia is relatively well provided with topographic mapping down to 1:50,000 scale, as well as thematic mapping for geology, soils, erosion, vegetation cover and land use. Other physical inputs to CVA work are also available in report and similar formats. Accessing and applying as many relevant data sets as possible will strengthen a CVA.

***Are there elements of the road network that are particularly sensitive to climate variability and change because of location or condition?***

An early stage in the CVA process is classifying areas for sensitivity. The 2018 NTU CVA Report has identified areas in Zambia down to the district level where sensitivity is high. Further work is required to increase the level of detail of these assessments.

***Are there historical records that identify particular areas of exposure (flooding, landslips, high runoff damage to bridges and culverts)?***

Systematically collected data on road sector climate impacts remains poor and needs to form a key part of future highway management system input formatting. Nevertheless, there are sufficient records and anecdotal sources to permit CVA work to be completed satisfactorily in most parts of the country.

*Are some parts of the road network more critical to the national or local economy, or to social delivery than others?*

A criticality assessment is also an early requirement of a CVA. Again the 2018 CVA Report analyses criticality in the road transport network, although further risk assessment inputs are needed to increase the comparative criticality of specific road sectors and segments.

*How is the current road network vulnerability likely to be impacted by any increase in climate variability or change?*

Having established a baseline vulnerability, the next stage is to assess projected changes in climate on that vulnerability. The 2018 CVA study provides an indication of the vulnerability of the national road transport network to climate variability and change within current information frameworks. Future work will be able to improve the definition of the 2018 findings as improved inputs become available.

Modelling can start once the initial questions have been answered. The CVA analytical process then creates an overlay for each of the key factors in order to measure the overall, composite vulnerability of each part of the road network. Geographical Information Systems (GIS) provide a very useful tool for this work as they can map individual parameters, store the associated information in a geographically-linked database, overlay them, and provide a multi-variant analysis of the various information layers to generate a composite vulnerability index for each mapping area or point.

A CVA is targeted at a specific scale (it may be at a national scale, or a larger scale – for example a particular city, or even a part of a city). Consequently, where funds permit, there are advantages in starting at the small scale (say national) to establish general patterns. Thereafter, the level of climate proofing of the road network can be developing from those results with assessments at district or city levels, or for particular areas of vulnerability.

As with all analytical systems, the quality of the inputs largely determines the quality of the outputs. In particular, information for a road sector CVA may be limited by the paucity of reliable inputs. For example, the collection of data on climate impacts on road infrastructure will usually be in a more general road condition survey format. As a result, impact causation cannot easily be differentiated between factors such as inadequate design, poor construction, insufficient maintenance, or a weather event outside the design parameters. Thus, where possible, it is useful to gather appropriate information from other sectors as this can increase the reliability of inputs to the GIS analysis.

Similarly, information collected may be at a wide range of spatial resolutions or have occurred before an improvement in the road network, rendering it less valid. The CVA process, therefore, also requires a reasonable degree of experience, institutional memory and flexible thinking.

## **2.4 International best practice in climate vulnerability assessment**

Climate vulnerability assessment is a new field in Zambia. In order to maximise lessons learned so far, the Project reviewed best international practice, (including the reasons one might undertake a CVA) leading methodologies and reliable sources of information.

The specific design of a CVA depends on the reasons it is being undertaken and the focus of the application (for example: infrastructure, agriculture, health or others). Nevertheless, the essence of these assessments remains the same, based on a common understanding of core concepts and logic; a combination of anthropogenic and natural climate and weather-related effects constitute hazards. These are applied to socio-economic and environmental baselines that will determine their respective exposure to the hazards and their vulnerability to them. The area of overlap between hazards, exposure and vulnerability determines the level of risk associated with the particular hazard.

A clear understanding of the dynamics of the relevant systems is equally important:

- an in-depth understanding of the nature of the changing environment (characterisations of future climatic, other environmental and socio-economic conditions: where and how fast);
- understanding the potential impact and extent of impact on the infrastructure in as much detail as possible; and
- having an estimated time frame for changes taking place and/or the probability and return period of disastrous events.

Two best practice guides for road transport sector CVA methodologies are described briefly below. They provided useful starting points for this CVA for the Zambian road transport network. They are described in detail in the full Climate Vulnerability Assessment Report of 2018.

#### **2.4.1 World Bank Group: Prioritising climate resilient transport investments in a data-scarce environment: A practitioners' guide<sup>3</sup>**

This guide comes out of work conducted using financial support from the Africa Caribbean Pacific (ACP)–European Union (EU) Natural Disaster Risk Reduction Programme, received through the Global Facility for Disaster Reduction and Recovery (GFDRR). It was implemented to demonstrate that disaster risk resilience and broader climate resilience could be successfully integrated into national development goals. It presents an example drawn from Belize.

Given the complexity associated with increasing the road network resilience and in the context of limited available funding, the Government of Belize wished to identify areas of the road network that were of highest risk and highest socio-economic criticality. The objective was to direct resources toward the highest climate resilience-enhancing initiatives. The World Bank Group Global Facility for Disaster Reduction and Recovery worked with the Government to complete an assessment and prioritisation that resulted in identified investments in improved key road segments that would increase the country's resilience to the impacts of natural hazards (Figure 14).

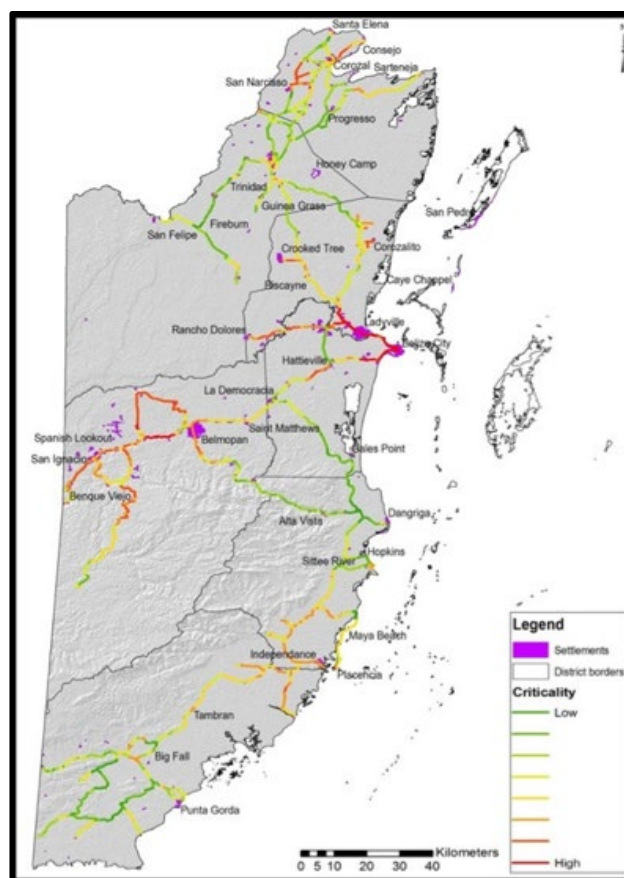
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<sup>3</sup> <http://documents.worldbank.org/curated/en/818411499808641786/pdf/117375-WP-PUBLIC-P127338-Practitioners-Guide-to-Prioritizing-Climate-Resilient-Transport-Investments.pdf>

The prioritisation process and lessons learned from it provide guidance for a general methodology, a conceptual framework, and a case study of the process that was conducted in Belize. It specifically addresses the challenges of environments where data is scarce.

The conceptual framework consists of six modules presented sequentially in practice; however, their implementation may be both in parallel and iterative:

- a) definition of objectives and scope of the prioritisation process;
- b) understanding the governance context and establishing the institutional arrangements for the process;
- c) collation of data, focusing on identifying and bringing together existing data, and the creation of new data to fill the data gaps;
- d) evaluation of criticality;
- e) assessment of risk/exposure from climate-related hazards;
- f) informing decision making.



**Figure 14: The CVA outcome from a World Bank study for Belize study**

Source: World Bank, *Prioritizing Climate Resilient Transport Investments in a Data-Scarce Environment, A Practitioner's Guide*

## 2.4.2 World Road Association (PIARC): International climate change adaptation framework for road infrastructure<sup>4</sup>

This framework is similar to the World Bank but has been developed by the World Road Association through extensive research and consultation with road authorities globally. The objective is to guide authorities through identifying relevant assets and climate variables for assessment, identifying and prioritising risks, developing a robust adaptation response and then integrating findings into a decision-making process. The framework provides a lifecycle and iterative approach to climate change adaptation.

The framework comprises the following process:

- a) identifying the scope, variables, risks and data for the assessment;
- b) assessing and prioritising risks;
- c) developing and selecting adaptation responses and strategies;
- d) integrating findings into the decision-making processes.

## 2.5 The climate vulnerability assessment methodology adopted by this project

The two standard CVA approaches described above have both adapted the core conceptual approach of a CVA specifically for the road infrastructure sector. The approach taken in this CVA draws from both of those.

To carry out a climate vulnerability assessment specifically for a road transport system, an important first step is to answer questions such as:

- 1) what assets serve critical economic or social protection functions and should thus be prioritised? (the **Criticality** of assets)?
- 2) what parts of the transport network are most vulnerable and why? (their **Sensitivity**)?
- 3) what are these elements vulnerable to? (their **Exposure**)?
- 4) how will their vulnerability change under a changing climate? (**Future risk**)?

This study used the following methodology, based on a GIS platform:

### **Step 1 - The collection of data**

Step 1 included investigating the types of data available and the resources available to collect additional data - both influence the choice of analysis approach and type of model used to analyse the criticality and climate risks of the road networks.

Consequently, once the objectives were clearly articulated, a quick list of the kinds of data that could support the assessment of options to achieve the objective was prepared with a scan of the immediately available data sets, their scale, and their attributes. **Both data collation and collection are iterative processes** and were conducted in parallel to all of the other steps. While the scope and objectives of the prioritisation process provide an initial indication of the data sets needed, ultimately, the criticality and hazard/risk model selection and setup determine the final list of required data sets and attributes.

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<sup>4</sup> <http://www.piarc.org/en/order-library/23517enInternational%20climate%20change%20adaptation%20framework%20for%20road%20infrastructurehtml>



In this case the availability of good quality data proved problematic in both the completeness of data sets and the quality and standardisation of recording.

## **Step 2 - The criticality evaluation**

A multi-criteria analysis (MCA) approach was used to define criticality, i.e. those assets that serve critical functions, such as guaranteeing connectivity to production centres, or providing access during times of emergency.

Road investments need to target areas and locations that are strategically important to the Government's development goals, including social, economic, and other considerations. An MCA is a flexible tool that can be used to evaluate the socio-economic impacts arising from interruptions in the transportation network based on the importance of the road network and its various segments to the people and the economy (thus its 'criticality').

Criticality determines the relative importance of some parts of the network over others. The concept of transport network criticality aims to identify the most critical assets by evaluating the relative importance of the sector assets with respect to:

- crises and emergency management;
- linkage to important economic hubs; and
- prominence in the connectivity of vulnerable communities.

## **Step 3 - Risk assessment**

This was undertaken by analysing the probability of potential climate/weather hazard impacts through assessing exposure and vulnerability risks that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

Climate stressors were catalogued by a combination of analysing ZMD climate parameter trends and global climate models. Apart from temperature, other climate parameters have limited projection capacity because of high levels of uncertainty.

The risk assessment was based on the review of exposure and sensitivity criteria described earlier and expanded here:

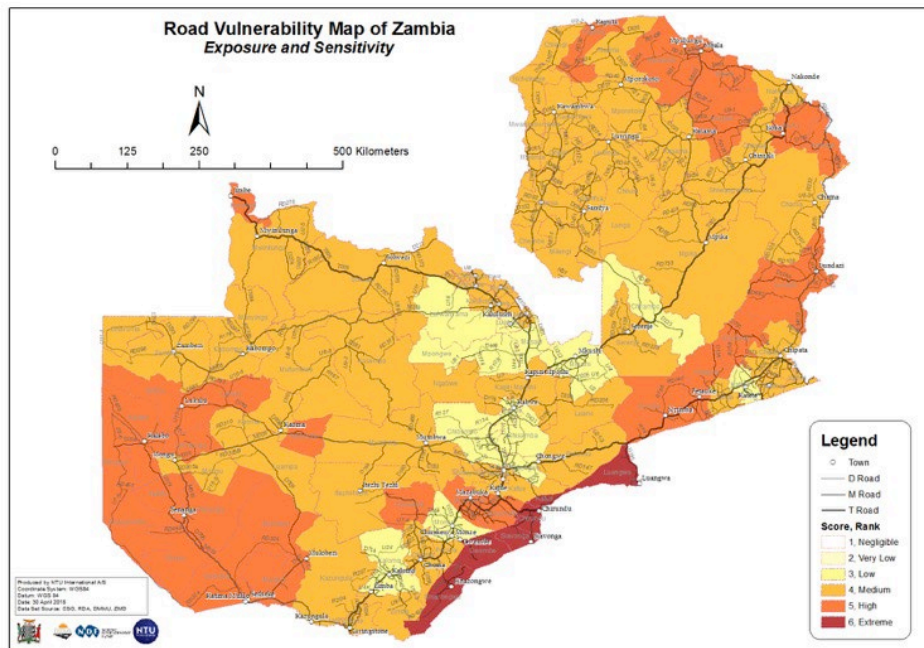
***Exposure*** is a function of location and represents the direct and indirect risks posed by weather- and climate-related hazards. Assessment of exposure is informed by existing levels of exposure (to the impacts of climate change) based on historical and recent events, local and technical knowledge and research, as well as future exposure levels to different climate change effects informed by analysis of climate change projections.

***Sensitivity*** is the predisposition to be adversely affected by climate related hazards, defined by:

- geographic location (wetlands, mountains, ecologically sensitive);
- road asset structural characteristics (gravel or bitumen) and asset condition;

- critical crossing points that may have an adverse effect on the overall network if compromised;
- higher risk was also associated with heavier traffic on a particular link in the network;
- experience of recent and historical climate and weather-related events.

Figure 15 illustrates the outcome of district exposure and sensitivity analyses for Zambia’s road network in 2018.



**Figure 15: District climate risk exposure and sensitivity analysis outputs for the Zambian road network**

Source: *NTU Climate Vulnerability Assessment Report, 2018*

#### **Step 4 - Economic evaluation of climate impacts on road infrastructure**

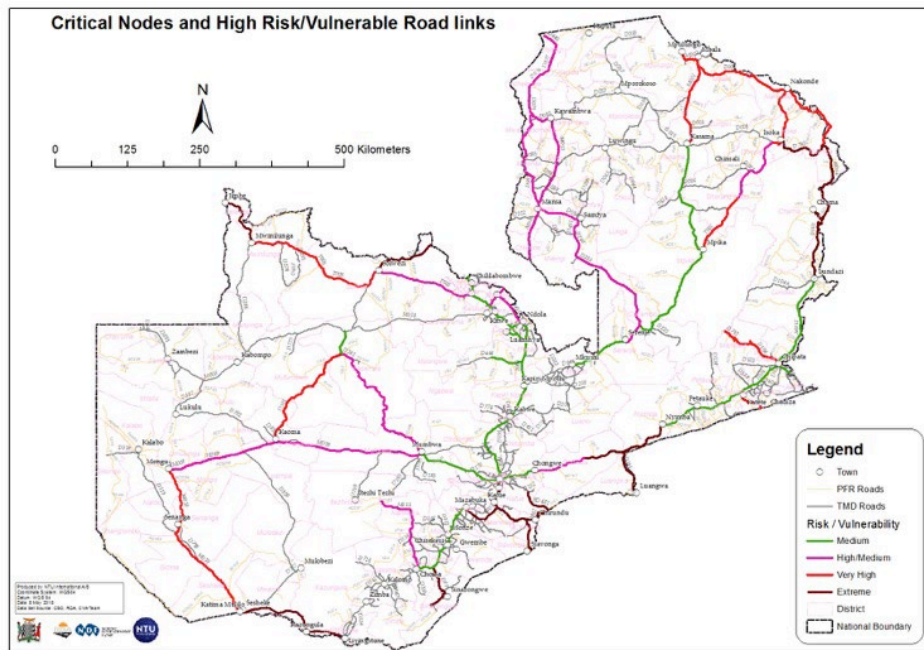
This stage evaluated the economic costs due to past exposure to climate and weather events in Zambia and of projected future climate impacts. The objective, ideally, was to catalogue climate impacts on infrastructure, by category (e.g. paved or unpaved roads) and by key stressors (e.g. precipitation and temperature). The process was constrained by severe data deficiency, but involved:

- 1) assessing the financial and economic costs of historical climate change/weather event impacts on road infrastructure by type (available data was all precipitation- and flood-related):
  - a) assessing the **direct** economic costs due to damage to infrastructure assets; and
  - b) assessing the **indirect** economic costs in infrastructure operating and servicing costs (a paucity of economic multiplier impact data limited the analysis to engineering indirect costs);
- 2) development of a cost-calculation framework by type of climate stressor and type of road surface (similarly the paucity of robust data limited the analysis to precipitation and temperature stressors; the latter being subject to several caveats);

- 3) evaluating projected future climate-related impacts on the paved and unpaved road network.

### **Step 5 - Analysis of options for strengthening adaptive capacity to climate and weather event stressors**

The prioritization of road sector assets was then carried out, based on the analysis of results from the criticality and the climate hazard assessments. This step provides insights into how the results can be prepared for and used by decision makers, for example with **vulnerability matrices** (effectively a criticality scale that uses an MCA to analyse sensitivity and exposure indices). These are then presented in a format that decision-makers can use in the form of **vulnerability maps** (Figure 16).



**Figure 16: Climate critical vulnerability in Zambia's road network**  
 Source: NTU Climate Vulnerability Assessment Report, 2018

A key question is, what are the specific, incremental and transformative pathways that will change the underlying risks to adverse impacts? Both operational and technical adaptation options were examined:

- 1) adaptation through an integrated and flexible Inter-modal Transport Network;
- 2) technological changes or modifications to infrastructure (e.g. soft engineering options); including changes to maintenance procedures and standards.

### **Future inputs**

It should be noted that while reviewing technological and process changes within the road transport system during this CVA study, important recommendations emerged for:

- the development of climate resilience knowledge base and data management processes (Information and Knowledge Management and Learning); and
- adequate training in decision support tools that will assist in implementing future CVAs and the associated process to climate adaptation and resilience-strengthening decision-making in future.

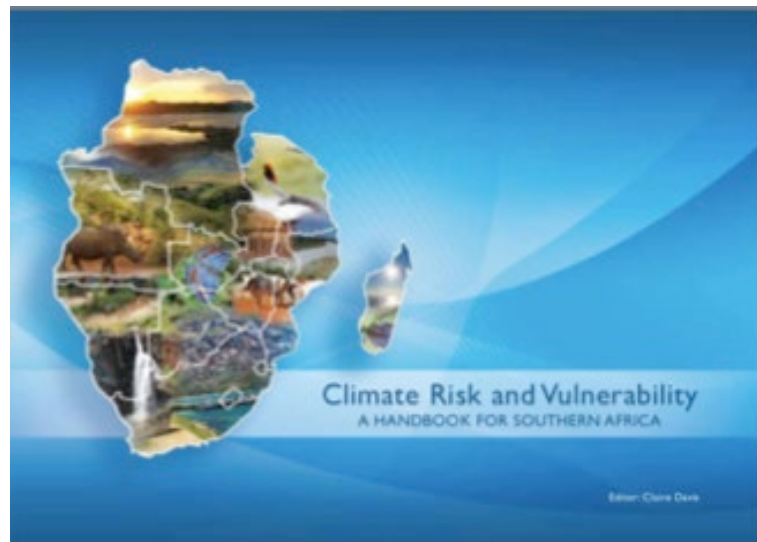
## 2.6 Other relevant climate resilience initiatives providing information sources

A wide range of CVAs now exist for road networks around the world for situations ranging from rural Cambodia, to state highway authorities in the United States of America, and island nations in the Caribbean and Pacific. Together they provide a useful guide to how CVA issues have been addressed in different situations and the parameters that have been applied. Many more assessments are on-going, all usually accessible through web searches.

Within Zambia and the region there are several useful initiatives. Climate resilience is increasingly being mainstreamed, with a Climate Proofing Manual for Financial Planning being used to inform the 7th National Development Plan (7NDP). This will be progressively rolled out to district planning and budgeting. Other local and regional initiatives include:

- **the Pilot Programme for Climate Resilience (PPCR)**, a regional and global initiative under the Multilateral Development Banks Strategic Climate Fund (SCF). A Zambian component, funded by the African Development Bank (AfDB) includes the rehabilitation of selected strategic roads in the Kafue sub-basin to meet climate resilience criteria;
- **the Climate Adaptation Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa (UKAid-funded) Africa Community Access Partnership (AfCAP)** research programme;
- **the African Climate and Development Initiative (ACDI)** which is a university wide initiative at the University of Cape Town that supports collaborative inter- and trans-disciplinary research and training in climate change and development;
- **the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL)** is a joint initiative of Angola, Botswana, Namibia, Southern Africa, Zambia and Germany to address the challenges of the global changes in climate;
- **the Southern Africa Climate Finance Partnership (SACFP)** supports the development of a regional partnership to improve country-owned climate finance portfolio;
- **the Future Climate for Africa (FCFA)** programme is funded by UKAid and the Natural Environment Research Council (NERC) with four sub-programmes including the **Future Resilience for African Cities and Lands (FRACTAL)** project intended to deepen urban policy-makers understanding of climate change and its impacts on and possible resilience options for water and energy services;
- **the Improved Rural Connectivity Project (World Bank-financed)** is applied to:
  - Improve the recipient's rural road accessibility for communities in selected areas;
  - Strengthen institutional capacity for sustainable management of rural roads; and
  - Respond promptly and effectively to an eligible crisis or emergency. The programme has been screened for short and long-term climate change and disaster risks;

- **the Climate Risk and Vulnerability: A Handbook for Southern Africa, (2017)** (South African Council for Scientific and Industrial Research [CSIR]) that is be widely applied in the region (Figure 17).



**Figure 17: Climate Risk and Vulnerability: A Handbook for Southern Africa**

### 3. Sources of information, capacity and gaps relevant to climate vulnerability assessments as a tool for road sector planning and management in Zambia

As noted earlier, the quality and sufficiency of information feeding into a CVA will be a key determinant in the quality of the outputs from it. This section examines where climate-related data can be sourced, the capacity and limitations on those data, and where gaps exist. Full details are in the Climate Vulnerability Assessment Report.

#### 3.1 Key stakeholder organisations

The key player in Zambia's climate sector is the Pilot Programme on Climate Resilience (PPCR) in the Ministry of National Development Planning (MNDP) with an operational unit in the Department of Natural Resources and Climate in the Ministry of Lands and Natural Resources (MLNR).<sup>5</sup>

Until recently PPCR was the National Climate Change Secretariat in the Ministry of National Development Planning, a location that arguably offers an optimum cross-sector framework for the unit.

##### 3.1.1 Key transport stakeholder organisations

More specific to the transport sector, the key stakeholders include a wide set of line ministry and agency institutions responsible for road, rail, aviation and water transport.

The road sector itself has an equally complex institutional arrangement, with the four main road sector institutions (NRFA, RDA, RTSA and LRAs) spread across six ministries: Finance, Housing and Infrastructure Development, Local Government, Transport and Communications, Tourism and the Arts, and Defence. This complexity hinders sector coordination. The following institutions are all key stakeholders:

- National Road Fund Agency (NRFA): the financing agency for the road sector;
- Ministry of Finance (MoF): that hosts NRFA;
- Road Development Agency (RDA): responsible for the care, maintenance and construction of public roads in Zambia;
- Ministry of Housing and Infrastructure Development (MHID), RDA's host Ministry;
- Road Transport and Safety Agency (RTSA): implementing policy on road transport, traffic management and road safety;
- Ministry of Transport and Communications (MTC): responsible for the formulation and administration of transport sector policies, that hosts RTSA;

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<sup>5</sup> Previously variously named the PPCR in the Ministry of Finance, the National Climate Change Secretariat (NCCS) in the same ministry and more recently the NCCS in the Ministry of National Development Planning. Securing a stable, multi-sectoral location of the unit and institutionalising it has been proposed by several parties as being essential to meaningful development of the climate change monitoring, mitigation and adaptation in Zambia.

- Ministry of Local Government (MLG): Local Road Authorities (LRA) that comprise district and urban/city councils. Other LRAs include the Department of National Parks and Wildlife [DNPW] and the Zambia National Service [ZNS];
- National Council for Construction (NCC): addressing administration and registration of road contractors and the training of small-scale contractors.

In addition are the four institutions managing aviation, water transport and railways in Zambia, all under the umbrella of MTC:

- a) Zambia Airports Corporation Limited (ZACL): responsible for managing all of Zambia's international airports and air navigation services;
- b) Civil Aviation Authority (CAA): responsible for regulating the aviation sector;
- c) The Maritime and Inland Waterways Department responsible, inter alia for the regulation of all inland waterways;
- d) Zambia Railways Limited (ZRL) (which also manages the Mulobezi and Muchinji railways) and the Tanzania-Zambia Railway Authority ("TAZARA") railway operators.

### 3.1.2 Other key climate resilience-related stakeholder organisations

Other key stakeholders in the context of strengthening climate resilience in the road transport sector include the following important providers of information:

- the Disaster Management and Monitoring Unit (DMMU) in the Vice-President's Office;
- the Zambia Meteorological Department (ZMD) in MTC;
- the Water Resources Operations Directorate (WROD) in the Water Resources Management Authority (WARMA) in the Ministry of Water Development, Sanitation and Environmental Protection (MWDSEP);
- the Zambia Environmental Management Agency (ZEMA) in MWDSEP;
- the Survey Department in the Ministry of Lands and Natural Resources (MLNR);
- the Geological Survey Department (GSD) in the Ministry of Mines and Minerals Development (MMMD); and
- the Soil Survey Unit in the Ministry of Agriculture (MA).

## 3.2 General principals of data collection and management

The objective of this climate change vulnerability assessment is to examine the resilience of the road network to the effects of climate change and extreme weather and how that may be enhanced. Information and Knowledge Management (IKM) is key to the development of a sound assessment and involves integrating the collection, processing, organization, storage and dissemination of information. Equally, it seeks the leveraging of people, resources, processes and information in order to secure informed decision-making and coordinated action.<sup>6</sup>

In order to achieve these aims, the following principles should be followed:

- a) systematic collection of data at scale that is precise and accurate;

<sup>6</sup> UNISDR, 2013. *Information and Knowledge Management for Disaster Risk Reduction (IKM4DRR) Framework and Scorecard*, UNISDR/GE/2013/10. [ONLINE]: [www.prevention.net](http://www.prevention.net)

- b) there is coordination and harmonization among implementing agencies with respect to:
  - common data definitions, standards and structuring in order to improve data system interoperability among different stakeholders;
  - foster open data and hybrid systems to accelerate adaptation under conditions of uncertainty;
- c) IKM systems should seek collaborative partnerships to avoid duplication of effort; ideally with national and regional initiatives, local and national institutions and agencies sharing data, expertise and information guided by policy;
- d) creating web-based spatial data infrastructure which is embedded in preparedness and response information management systems;
- e) systems are managed and up to date; with quality control mechanisms in place;
- f) all IKM systems and actions should be based on a thorough user needs analysis;
- g) communication and collaboration with and between users and stakeholders is central to achieving strategic objectives;
- h) good practice, failures and lessons learned should be shared;
- i) information should be captured and made freely available for analysis, co-creation and synthesis where appropriate.

Data requirements fall into a number of categories:

<b>Infrastructure:</b> Road asset classification; intermodal connections, etc.
<b>Climate data:</b> Historical, current and projected.
<b>Socio-economic vulnerability:</b> To determine the strategic importance of the roads, examining parameters such as the location of economic hubs, population distribution and urbanisation.
<b>Geographical context:</b> Environment and ecology, including topography and slope; soils, water bodies and land cover.
<b>Safety and security:</b> Disaster preparedness.

Conducting a climate vulnerability assessment of the road transport sector in Zambia presented challenges on a number of fronts: the scarcity of reliable data, data system interoperability among different stakeholders, and, *inter alia*, a reluctance to share data even when it is available (in the absence of a strong culture of communication and collaboration with and between users and stakeholders, despite it being central and strategic to coordinated action). This increases uncertainty and reduces the flow of critical information to and among local decision-makers and stakeholders.

### 3.3 Sources of and limitations to climate- and weather-related data

#### 3.3.1 Sources of climate data

The Zambian Meteorological Department (ZMD) is the primary weather and climate observing institution in Zambia. It manages an operational network of 37 automated (now being increased to more than 100) and numerous manual weather stations across the country. These sources are supplemented by networks operated by other institutions.



New initiatives such as the previously mentioned Southern African Science Service Centre for Climate Change and Adaptive Land Use (SASSCAL) also provide data contributions.

ZMD climate records extend back for more than 100 years and theoretically offer considerable opportunity for the mapping of climate trends. However, almost all historical records before the 1990s are still in hard copy field format, or in ZMD reports of averaged annual climate data (until the late 1970s).

As a result of this lack of primary observed data in digital format for Zambia, much of the work on historical climate trends and variability analysis is dependent on merged satellite and re-analysed data products. Some specific analyses have been undertaken by ZMD but the World Bank Climate Change Knowledge Portal is a good real-time source of analysed data for Zambia (see Section 1.5 earlier).

The ZMD generates and disseminates daily, weekly and seasonal weather forecasts and climate projections with the aim of supporting application in various sectors, such as agriculture, hydrology, health and disaster risk reduction (through early warning notices).

Data analysed to date has also been used in contributions to Zambia's annual contributions to the UNFCCC, and to various global climate-modelling efforts at universities in Europe, South Africa, the United Kingdom, the United States and elsewhere.

### 3.3.2 Limitations on climate and meteorological data

The present status of the ZMD data collection infrastructure is a major constraint to securing robust, current and future climatological and meteorological data. The operational weather stations are not identical, and the density and capacity of meteorological stations also varies widely, even in key hydrological catchments. Compounding these issues there is insufficient funding to support regular and systematic data collection, monitoring visits and necessary maintenance.

A further limitation on the use of Zambian climate data is the abundance of records that are still awaiting digitisation and, therefore, inaccessible for computer analysis. ZMD has an on-going programme of digitising records but with limited resources this will be a lengthy process. Some of these data are available to researchers through global station data archives such as the **Global Historical Climatology Network**. However, for many stations, publicly available records end in the late 1990s or early 2000s, which limits analysis of recent variability and trends.<sup>7</sup>

There is also a need to strengthen the institutional and operational framework for national climate information in Zambia. This should include clarity with respect to the sharing of climate information (including collection, standardisation and dissemination of climate data), and a strengthened capacity for routine data collection and analysis, as well as applied modelling and forecasting.

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<sup>7</sup> Jack, C., Wolski, P., Izidine, P. and Indasi, V., 2016. *Africa's climate: Helping decision-makers make sense of climate information*. *Future Climate for Africa*. p. 4.

### 3.3.3 Hydrological data source limitations

While climate and meteorological data are essential inputs to CVA vulnerability assessments, the availability of good quality hydrological data permits the more robust modelling of rainfall-runoff relationships and flooding. Hydrological recording was the responsibility of the Department of Water Affairs, but that role has now been moved to WARMA. However, similar shortcomings to those in ZMD exist and currently only 69 automated river flow stations are operational and there are also similar gaps in the hydrological digital record and in the calibration of river rating curves.

## 3.4 Sources of road sector data and their limitations

### 3.4.1 Sources of road sector data

RDA has systematic data inventory systems for road condition, bridge condition, traffic counts and axle load control. All these data are theoretically collated and managed through RDA's Highway Management System (HMS) database. Road condition data attributes in the HMS database include surfacing type, pavement layer thicknesses, date of construction, maintenance history and so on.

RDA's periodic traffic counts are at 64 locations across the road network. Axle load control data is delivered to the Axle Load Control office in Lusaka from automated weighbridges on the Trunk and Main road networks.

Road condition data (up to 2015) exists for about 87 % of road segments in the Core Road Network (CRN) (road segments are the links between nodes in the road network), permitting the road condition and traffic levels to be collected, stored and analysed for specific segment locations.<sup>8</sup> Road condition surveys have been conducted on Zambian roads since the establishment of the Road Sector Investment Programme (ROADSIP) in 1998.<sup>9</sup> Paved roads are assessed using the International Roughness Index (IRI) format. Unpaved roads are assessed using a Visual Rating scoring from 1 (ride very smooth) to 5 (impassable). ROADSIP-administered condition surveys were conducted in 2009, 2011, 2013, 2014 and 2015. They indicate a generally improving situation for the Trunk, Main and District (TMD) road network, but declining conditions in the feeder road system.

Road condition surveys of the CRN are an important aspect of the maintenance process and are carried out through the use of a private consultant. The RDA has developed the Road Condition Data Collection Procedures (for road condition and inventory) and the Bridge Inspection Manuals (for bridges) to standardise and quality control the collection of condition data on roads and bridges, but both still await full implementation. Neither procedure includes specific approaches to recording climate impact data.

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<sup>8</sup> World Bank, 2017. *Zambia: Improved Rural Connectivity Project, Transport & ICT Global Practice: Africa Region, Report No: PAD2002*, World Bank, Washington.

<sup>9</sup> *There has been an additional road sector investment programme – ROADSIP II (2004-2013) – that concluded in 2012. A further phase is now under design but in the interim investments are being made under the Road Sector Framework (2012-2022).*

### 3.4.2 Limitations on road sector data

The Ministry of Communication and Transport (MTC) has been developing the National Transport Sector Data Management System (NaTS-DMS) as a planning tool that will integrate transport sector data management (including road sector data) but this system too, is yet to be fully operational. The Ministry also recently completed the National Transport Master Plan (NTMP). The document usefully highlighted what data exists and what is lacking, but important issues are overlooked. Filling the gaps will help the MTC and MHID invest resources in the areas where and when they are most needed.<sup>10</sup>

A key issue is the lack of strategic and tactical data regarding the transportation sector in Zambia. It is recommended that other sectors follow RDA in completing regular data collection activities in their given arena of responsibility. Currently the Surveyor General in the Ministry of Lands is undertaking a nationwide project to create a GIS portal for government use with the highest-level technology. If MTC MHID and RDA could integrate their GIS activities into this format it would enhance transport sector information sharing.

The RDA collaborates with the Disaster Management and Mitigation Unit (DMMU) when dealing with emergencies that affect road infrastructure. Under this collaboration, the RDA provides the technical expertise and execution of the emergency works while the DMMU plays a coordinating role as well as providing a channel for financial support. However, inconsistencies exist between the two institutional inputs. Equally, differences in approach, scale and purpose underscore the need for a common standard for recording climate-related road sector damage.

Some of the main limitations of existing RDA and DMMU road sector data collection systems are:

- there is a lack of data that different failures due to natural causes from those to do with inadequate design and/or construction;
- the focus is on disaster response and not disaster risk reduction; however, this emphasis is changing as shown by RDA's new maintenance strategy;
- RDA's consolidated data on emergencies spans only five years and thus has limited application in climate vulnerability assessment;
- there is very little quality data concerning climate changes, disasters and consequent damage to road infrastructure; which affects the effectiveness of high-level studies and decision making;
- the Highway Development and Management Model (HDM4) is not yet adapted for climate resilience and is not fully utilised;
- road condition and traffic surveys are undertaken by RDA on a regular basis. But the most recent, complete set of surveys are from 2015, some 4 years ago;
- road condition surveys do not capture the condition of each culvert and do not differentiate between the different types of pavement failure. Furthermore, the surveys are not able to capture flooding incidents in the rainy season since they are done just after the rainy season. The surveys do not explicitly capture information on flood damage or accumulation of debris;

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<sup>10</sup> International Resources Group, 2010. *Zambia Environmental Threats and Opportunities Assessment*. United States Agency for International Development (USAID).

- there is a lack of nationwide data on gravel loss from district and feeder roads;
- RDA has a new Falling Weight Deflectometer (FWD) but it is still not operational as it awaits installation of software and calibration. RDA plans to have software installed and equipment calibrated before retraining an FWD-dedicated cadre of staff. The absence of such FWD data makes it difficult to assess the effect of temperature and moisture (rainfall) on the strengths of the various pavement layers;
- there is no capability for slope stability assessment and rock fall potential assessment. These could be carried out by use of sensors if funds existed;
- the current use of empirical design methods does not consider extreme weather events, nor do the methods incorporate emerging technologies, such as improved tyre design and climate change mitigation measures. For example, the increasing use of “super singles” (wide track, high pressure, single tyres replacing double tyres on heavy transport) for reduced fuel consumption. This makes performance prediction difficult as the dual tyre configuration is still the basis for the empirical design as the impacts on road deterioration rates of the higher tyre pressures in super singles still need to be evaluated.

Financial constraints are central to the paucity of, and gaps in, the road sector database, however, institutional and technical weaknesses are also contributory factors. Ideally axle load control data, traffic data and road condition data should all be obtainable from the single centralised office at the push of a button. But varying responsibilities, database systems, access protocols and the absence of a GIS platform in RDA all militate against efficiencies in data delivery, analysis and use.

### 3.5 Environmental data sources and their limitations

Despite the existence of a variety of institutions dealing with natural resource management (NRM), Zambia does not have in place a coordinating governance structure, policy, or legislation that brings together the ministries tasked with planning, implementing, and monitoring integrated natural resource management plans.<sup>11</sup> While the Zambia Environmental Management Agency (ZEMA) is required to maintain an environmental information repository in a manner that is accessible to the public, there are no data sharing protocols, common environmental data collection systems, nor specific requirements for agencies, projects and programmes to provide environmental data to the depository other than for licensing purposes.

In addition, ZEMA has no mandate to meet demand for, or provide environmental data to agencies and programmes. Inter-agency turf protection limits the level of environmental data sharing; for the most part government departments and agencies often treat environmental data as proprietary and a ‘source of strength’ in funding negotiations. As such they are not always willing to share it. Given that there is not a national environmental data and information management system in place, nor are there accepted standards, inadequate measuring, reporting and verification (MRV) capacity affects the availability of good baseline and verifiable data.

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<sup>11</sup> *Ibid.*

Most of the environmental data collected is either part of internationally mandated Multilateral Environmental Agreement (MEA) reporting obligations, or as part of a specific project covering a discrete geographical location. Among the most relevant environmental conventions to the road sector is the UNFCCC, which has a principal role in monitoring global GHG emissions and their impacts on the global climate.

National reporting obligations under the UNFCCC, the Convention on Biodiversity (CBD), and the Ramsar Convention (on wetlands of international importance) have driven the collection of environmental and biodiversity data at the national level. Projects and programmes such as the Integrated Land Use Assessments (ILUA) (2005-08; 2010-13), which provided a monitoring, review, and verification system for national land cover, and the Integrated Soil Fertility Management Project that responds to innovations towards climate-smart agriculture, spurred the collection of specific environmental data. In addition, university, civil society organization (CSO) and ad hoc private initiatives collect environmental data, but it is often limited to their areas of operations.

Project level Environmental Impact Assessments (EIA) and to some extent policy or programme-level Strategic Environmental Assessments (SEA) may generate discrete, site or regionally-specific environmental information, intended to inform decision making and project or programme environmental management planning. It is a requirement, for instance, that all major development projects, including road construction, carry out comprehensive EIAs. However, in practice these are often generic documents intended to fulfil the licensing requirements for a project and frequently relying on coarse scale environmental data.

### **3.6 Geographic information systems capacity and standardisation**

A Geographic Information Systems (GIS) capacity assessment exercise was carried out by this project to establish the level of adoption and use of GIS technology within the ministries, government agencies and departments that are key stakeholders in the road transport sector. The result indicated only low to moderate GIS capacity in relevant institutions.

Climate vulnerability and disaster risk information is spatial in nature, and GIS and remote sensing (RS) have important roles in generating databases and mapping for the various phases of information compilation, analysis, recommendations, and in planning, preparedness and response mechanisms.

The key gaps associated with risk and hazard mapping identified by this assessment included<sup>12</sup>:

- a paucity of shapefiles (GIS digital files holding the map data) for trunk roads and other roads;
- missing information on health and other infrastructure;
- different and often incompatible data set standards as collected by the different agencies.

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<sup>12</sup> DMMU. 2018. *Pers. comm.*

## 4. Zambia's Road Transport System and the Criticality of its Various Components

### 4.1 Road transport system asset criticality

A road transport sector CVA requires an analysis of which are the most important road segments and why they are important. **Asset criticality** measures the importance of any road sector in the context of the physical, economic and social outcomes that are expected if a given road link is lost – in this case to weather or climate-related impacts. If the asset criticality of certain road segments identifies that the risk of negative impact is small, these segments may be excluded from further consideration.

The 2018 CVA examined the chief factors that contribute to the criticality of Zambia's road assets using a multi-variate analysis. The factors considered were: economic centres, production areas, inter-modal considerations, population distribution and densities, socio-economic circumstances, accessibility, and landscape considerations. The location, interconnections and growth characteristics of the main economic hubs are important elements in the analysis followed the distribution of rural populations, their supply chains and the environmental hazards facing them.

### 4.2 Zambia's transport system

The key components of Zambia's transport system are:

- **Road:** Approximately 68,000 km of surfaced and unsurfaced roads. Valuable copper and cobalt products rely on convoy-based road transport using T1, T2, T3 and T5 trunk roads, which gives these roads higher criticality.
- **Rail:** 2,944 km of laid track (TAZARA 1,860 km, Zambia Railways main line 890 km, Mulobezi 167 km and Chipata-Mchinji 27 km).<sup>13</sup>
- **Air:** 4 international airports (Lusaka, Ndola, Livingstone, Mfuwe) and 46 aerodromes (with Mbala, Kasama, Mansa, Solwezi, Mongu, Kalabo having significant infrastructure);
- **Water:** Key nodes are a major port at Mpulungu (Lake Tanganyika) and minor ports at Nchelenge (Lake Mweru), Samfya (Lake Bangweulu), Siavonga, Chipepo, Sinazongwe (on Lake Kariba) and Mongu (on the edge of the Zambezi River system). The Bangweulu and Upper Zambezi floodplains together have approximately 2,700 km of canals.

The transport components are integrated through a number of intermodal connections, where road and rail, road and airport and/or road and water networks interface. These connections in turn support regional transport and trade corridors (Lake Tanganyika/Great Lakes Region, TAZARA/Dar-es-Salaam, North-South, Lobito, Chipata/Nacala, Beira and Walvis Bay). There are also several national critical intra- and

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<sup>13</sup> Rail freight constitutes a small fraction of the total cargo tonnage carried in Zambia (about 12%), because of track and rolling stock problems, inefficiencies and slow travel speeds.

inter-modal centres - Lusaka is the most important, others are Livingstone, Mongu, Chipata, Ndola, Chingola, Mpika and Kasama.

### 4.3 The road transport network and its management, key corridors and nodes

Zambia’s public road network is managed by RDA. Ministry of Local Government (MLG), has management responsibility for unpaved secondary and tertiary (community) feeder roads, Department of National Parks and Wildlife (DNPW) for national parks roads; City, municipal and district council for urban roads, both paved and unpaved. RDA provides the official road network data used by the Government. Data collection and sharing protocols between RDA and MLG are still not harmonised, constraining the collection and use of national road data.

The national road network comprises approximately 67,671 km of roads (Table 1), classified into Trunk, Main and District (TMD), Feeder (Primary, Secondary and Tertiary), National park and Community roads.

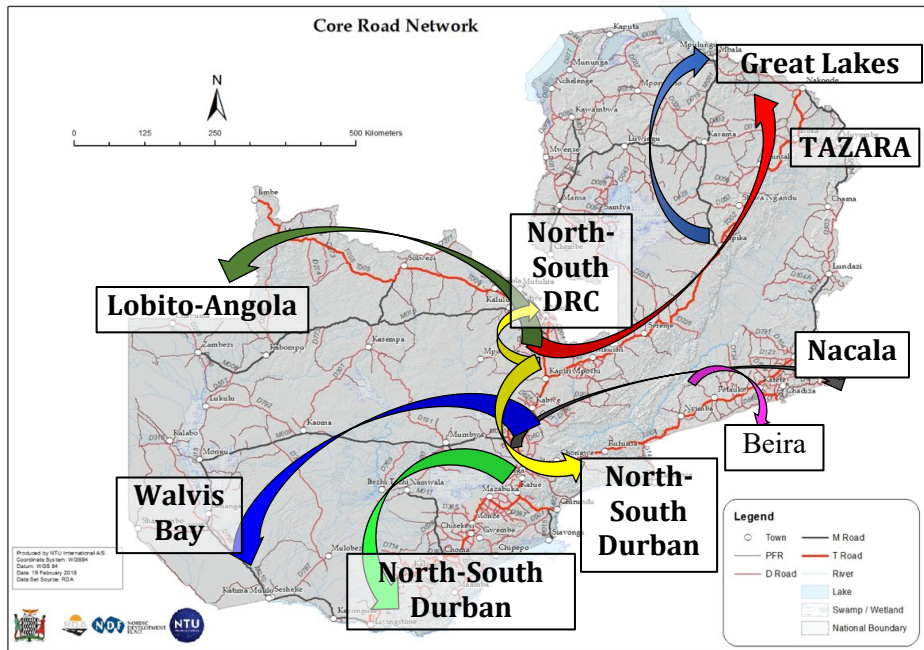
**Table 1: Zambia’s national road network lengths by designation**

Road Designation	Length (km)
Trunk	3,088
Main	3,691
District	13,707
Urban	5,2294
Primary feeder	15,800
Secondary feeder	10,060
Tertiary feeder	4,424
National park	6,607
Community	5,000

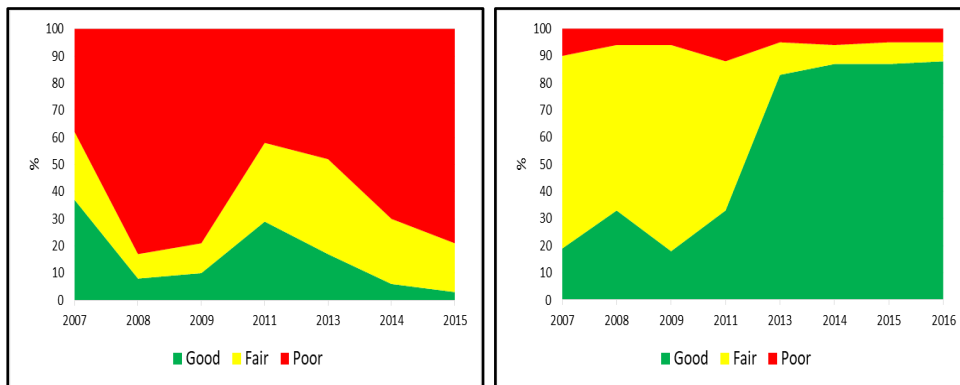
Source: Road Development Agency 2018

RDA focuses on a sub-set of the network total, **Core Road Network (CRN)**, which totals 41,511 km (about 61%), shown in Figure 18 which carry about **95%** of all heavy road traffic in Zambia. The regional corridors are superimposed. In recent years a maintenance policy decision was made to focus RDA efforts on the quality of the paved and unpaved road network has varied over the last decade but Figure 19 illustrates that the quality of unpaved network is much poorer than the paved network. Some 60% of the CRN currently requires major rehabilitation and only 40% is in a well-maintained condition.<sup>14</sup> Similarly, 82% (2015) of the Primary Feeder Road (PFR) network is in poor condition.

<sup>14</sup> SATRA. 2015. *Road Condition Survey*. RDA



**Figure 18: Map of Zambia's core road network and key regional corridors**  
 Source: Road Development Agency, 2018

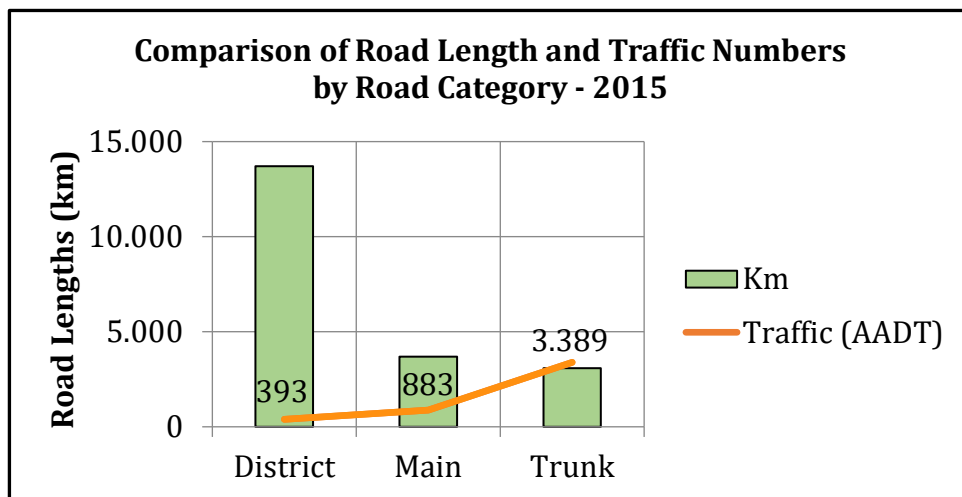


**Figure 19: Trends in Zambia's unpaved (left) and paved (right) road networks**  
 Source: Road Development Agency, 2018

The Rural Access Index (RAI), which measures the proportion of the rural population who live within 2 km of a good road, is currently estimated at only 17%. 6.9 million rural residents and small-scale farmers and traders (nearly half of Zambia's population) are poorly connected to the road network and less able to contribute to or benefit from the economy.



Trade corridors are vital to sustaining Zambia’s still import- and primary export-skewed economy. Zambia serves as a key regional trade crossroads, especially for heavy freight trucking, carrying valuable mining, construction, fuel and retail products. Trunk (T) roads, which function as both national and regional highways and carry up to 30% of heavy vehicles, are the most heavily trafficked. They carry four times more vehicles than Zambia’s Main (M) roads and 10 times more than the District (D) roads (Figure 20). Copperbelt Province and then Lusaka Province carry the most traffic because of their higher levels of economic activity and large populations.



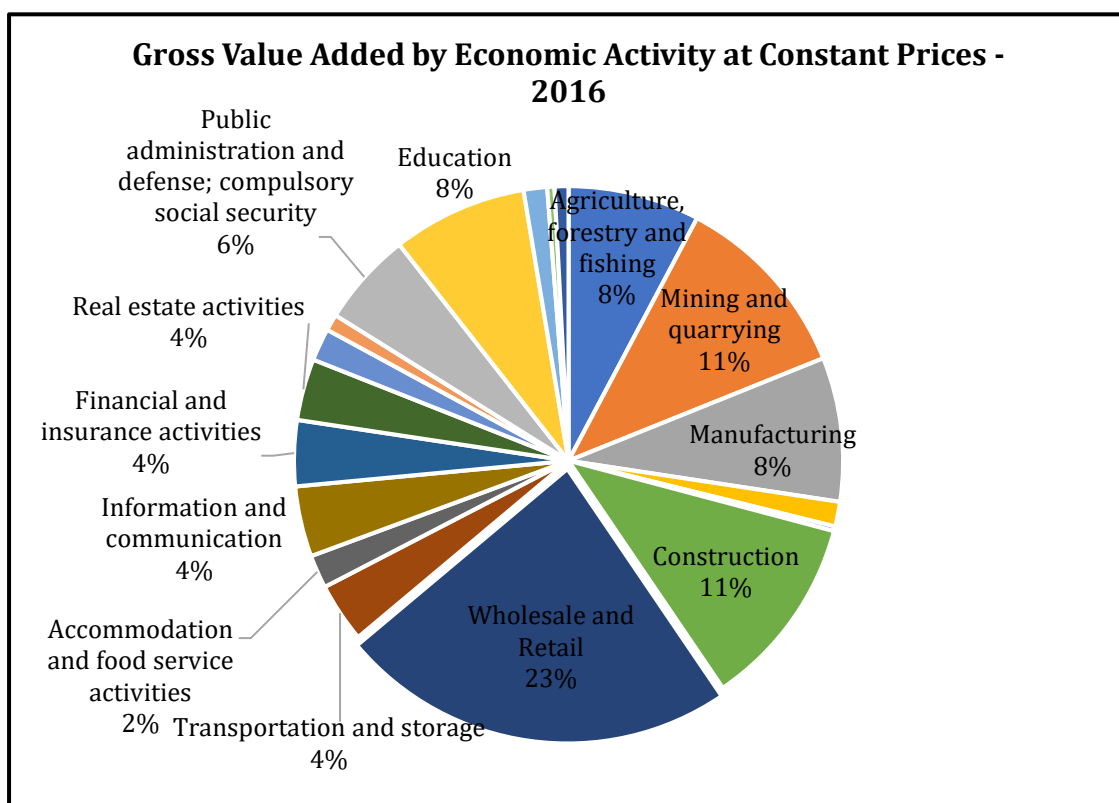
**Figure 20: Comparison showing the dominant importance of the relatively short length of trunk roads and the traffic carried on them**

Source: Road Development Agency, 2018

Annual traffic growth in the road network is also highest on the Trunk roads (9%), compared with 6% for both Main and District roads. All the provinces show very variable but growing annual increases, with Eastern, North-Western and Copperbelt the highest (between 11% and 14%). There are increasing demands and loadings being put on the country’s core road network, inevitably accelerating road deterioration, congestion and delays with consequent economic consequences.

#### 4.4 Principal economic sectors and activity zones

Figure 21 illustrates the contribution of economic sectors to Zambia’s GDP, highlighting the major contributions of highly transport-dependent sectors such as wholesale and retail, construction, mining, manufacturing and agriculture.



**Figure 21: Contribution to Zambia's Gross Value Added by Sector - 2016**

Source: Central Statistical Office, 2018

#### 4.4.1 Centres of economic activity and future trends

The heart of Zambia's economy lies within the Lusaka and Copperbelt conurbations, which host the majority of manufacturing and construction as well as service industry activities. The principal mining centre is also on the Copperbelt and now extending westward to Solwezi and beyond.

Commercial agriculture is also clustered, but more widely distributed along the 'line of rail' from Livingstone to the Copperbelt and north-eastwards to Mkushi and Serenje with small areas around Mbala. Small-scale agriculture is country-wide.

Tourism and fisheries are two sectors with considerable growth potential but with more remotely located nodes. Wildlife and adventure tourism is focused around Zambia's periphery in the Luangwa, Lower Zambezi, Kafue national parks and in Livingstone.

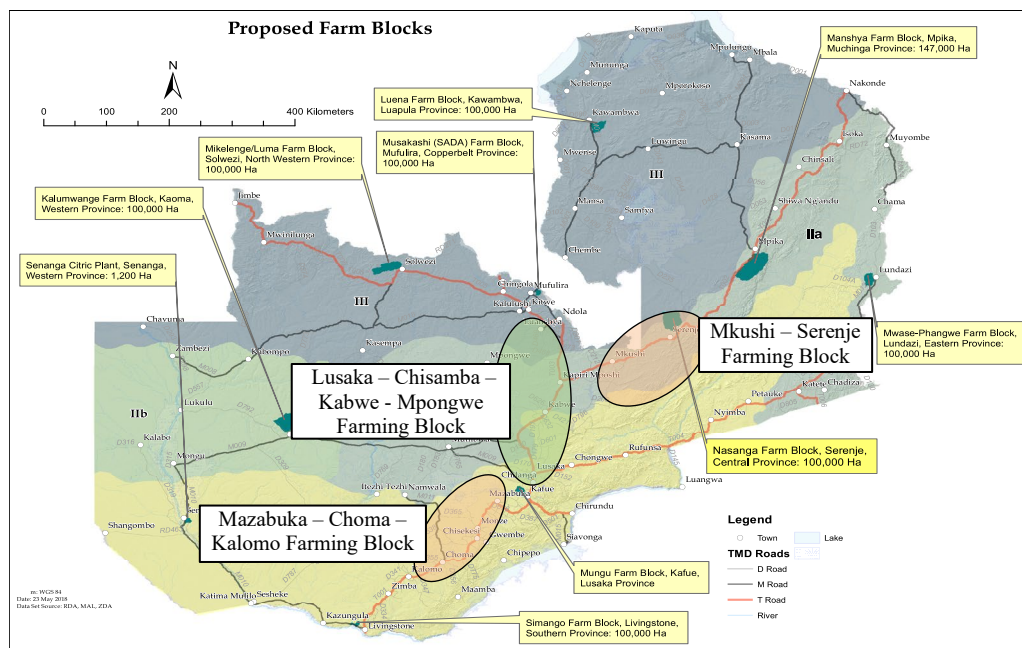
Fisheries production is also more remotely located, on Lakes Tanganyika, Mweru, Bangweulu and Kariba, but also along the Kafue River.

#### 4.4.2 The agriculture sector

Although the agriculture sector contribution to GDP has fallen recently from 25% to around 6%, the sector still supports 55% of the labour force, is the largest contributor to

national employment and has considerable production growth and value addition potential.

Key agricultural sector road transport criticality issues are time-critical input supplies and post-harvest produce deliveries (especially for perishable produce to local and air hub destinations) mainly on the T1/T2 and T4 networks. However, smallholder cropping is critically dependent on the climate-vulnerable rural roads network. In the next years the road network will need to respond to increased focus on diversification across the entire food processing system and expansion in existing farming areas and new government farming blocks (see Figure 22).



**Figure 22: Zambia’s agricultural areas and farm blocks**

Source: Ministry of Agriculture, 2018

#### 4.4.3 The mining sector

Copper and Cobalt are the key economic minerals and in recent years production has fluctuated significantly<sup>15</sup>. Nevertheless, the sector employs over 60,000 people<sup>16</sup>, mostly in the Copperbelt and adjoining areas with fewer employees in the more widespread coal, manganese, gold, nickel and gemstones production areas. The mining sector is heavily reliant on the trunk roads of the North-South, TAZARA, Beira and Walvis Bay corridors.

#### 4.4.4 The tourism sector

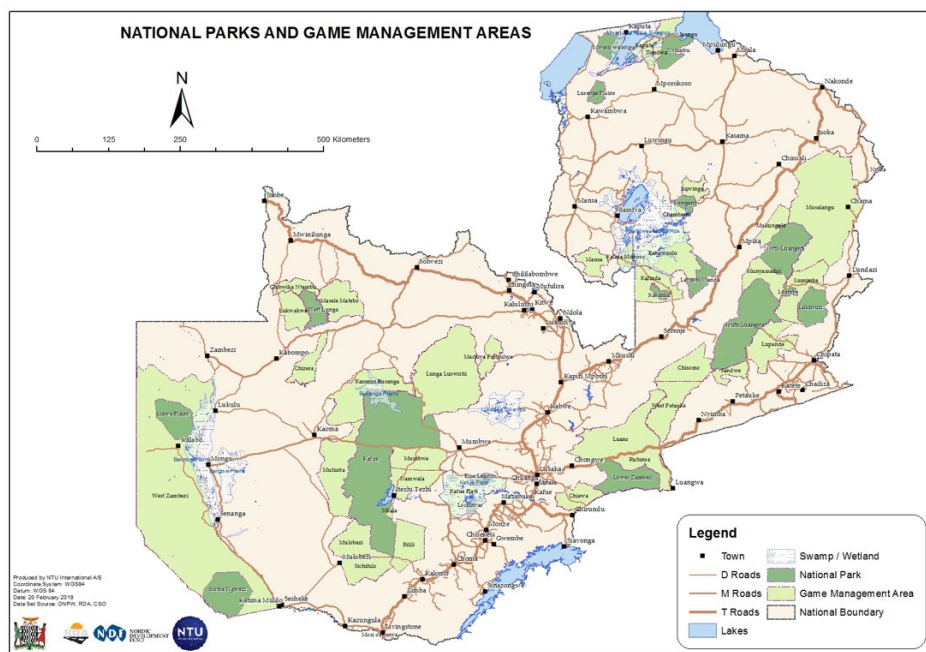
Tourism should be a main pillar of the Zambian economy but contributed only 3.5% to Zambia’s GDP in 2017. Tourism is, however, a foreign exchange earner and also important

<sup>15</sup> African Development Bank. 2017. Zambia Economic Outlook. [ONLINE] <https://www.afdb.org/en/countries/southern-africa/zambia/zambia-economic-outlook/>

<sup>16</sup> [ONLINE]: <http://org.zm/employment-figures/>

as a lever to the development of rural and urban areas through employment, supply chain and service industry investments. The country has a wealth of natural tourism assets and the highest percentage of formally protected areas in Africa (Figure 23) and numerous heritage sites.

Tourism sector road transport challenges include the large travel distances to tourism destinations, wet season accessibility, the high costs of domestic vehicle and air travel and insufficient critical mass to bring down operating costs. Further development of Zambia's excellent tourism opportunities will require considerable investment in Zambia's peripheral district and feeder road networks to make them viable.



**Figure 23: National parks and game management areas of Zambia**

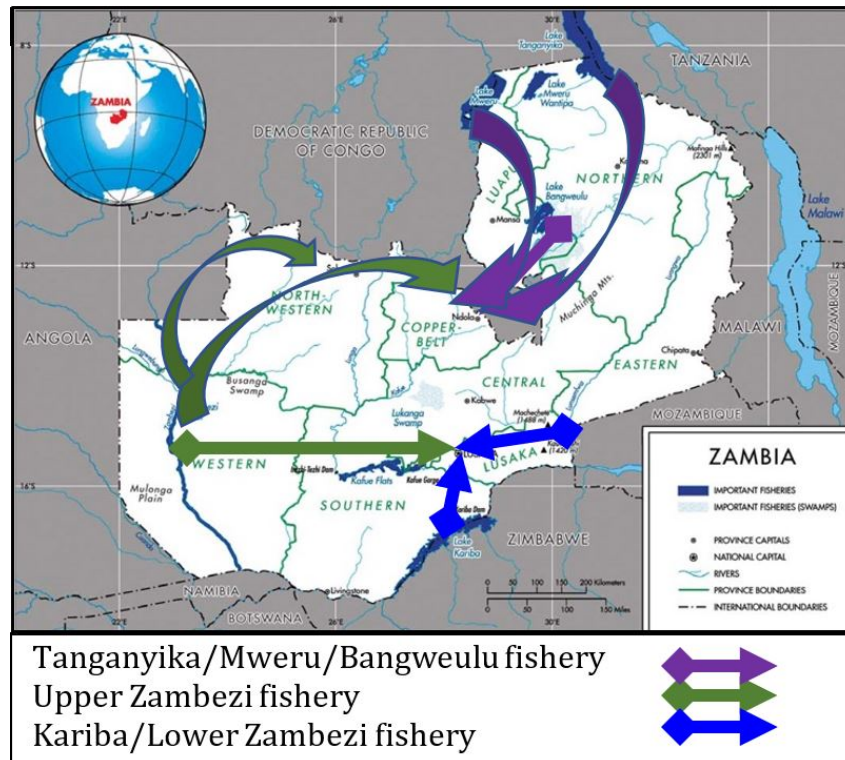
Source: DNPW, 2018

#### 4.4.5 The fisheries sector

Zambia has 11 main fisheries: four within the Congo River basin and seven in the Kafue and Zambezi River basins. The commercial (open-water aquaculture) fisheries on lakes Kariba, Tanganyika and Mweru are accessible via the Trunk and Main road systems. Small-scale fisheries are less well served but a major contributor to Zambia's economy, and nutrition and underpins rural incomes.<sup>17</sup>

<sup>17</sup> Musumali, M., Heck, S; Husken, M.C.; Wishart, M. 2009. *Fisheries in Zambia: an undervalued contributor to poverty reduction*. *WorldFish Centre Policy Brief No. 1913*. Washington, DC: World Bank. [ONLINE]: <http://documents.worldbank.org/curated/en/183191468170684519/Fisheries-in-Zambia-an-undervalued-contributor-to-poverty-reduction>

Road transport for the sector includes mainly T and M road access to national markets in the Central, Copperbelt and Lusaka Provinces from the key fisheries in the Western, Luapula and Northern Provinces. Fisheries in the Central (Lukanga) and Southern Provinces mainly supply the Lusaka market (Figure 24). The biggest regional destination market is DRC, but southern African states all import fish from Zambia (mostly as frozen fish requiring dedicated refrigerated transport and handling facilities).



**Figure 24: Fisheries and fish trading routes in Zambia**

Source: *WorldFish, 2009*

#### 4.4.6 The retail, wholesale and trade sector

Arguably central to the criticality assessment is the importance of trade utilising Zambia’s road transport system links to the region. Zambia shares borders with eight countries and is the link between Central, East and Southern Africa and an associated market of some 170 million people. Being landlocked, road networks are vital arteries to source key inputs from neighbouring countries and internationally. Trunk roads linking Lusaka and the Copperbelt are similarly important for the domestic trade and service industry sector.

The Government is investing in transport infrastructure, corridor development, dry ports and logistical improvements to transform the country from a landlocked into a land-linked country.<sup>18</sup> Nevertheless, Zambia for the foreseeable future will continue to be heavily on imported finished consumer products, intermediate inputs and machinery and semi-processed exported. These, and transit goods will continue to pressurise the country’s regional road transport network and volumes are expected to more than double by 2037.

<sup>18</sup> GRZ, 2013. *Road Maintenance Strategy 2014-2024*, RDA, p. 71.

This highlights the importance of the condition of the primary trade (and especially road) routes and of addressing their vulnerability to climate risks.

In rural areas the poor quality of feeder roads also constrains both input supply and demand and market linkage and delivery. Small improvements in the current poor quality of the PFR network will help to catalyse rural development through increased mobility and accessibility for domestic trade, particularly for agriculture and fisheries.

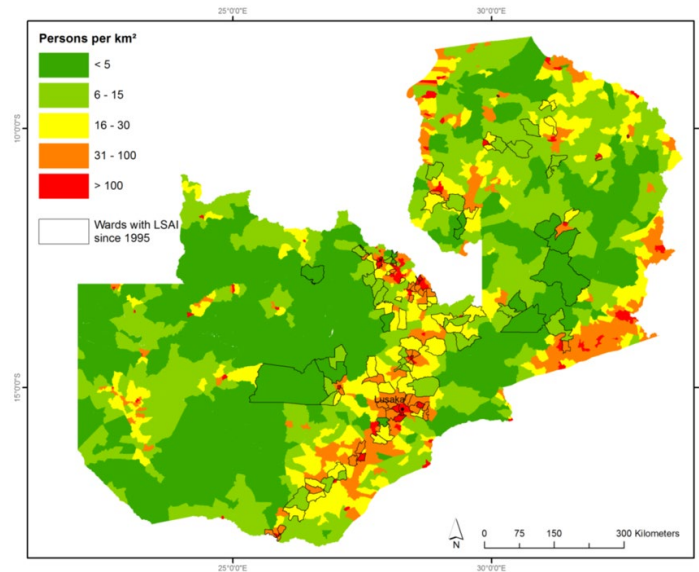
## **4.5 Socio-economic drivers**

While road transport links serving the productive sectors are important in a criticality assessment, social factors are of equal status. In particular, the distribution of population must strongly influence the national road network structure and distribution.

### **4.5.1 Population size, distribution and density**

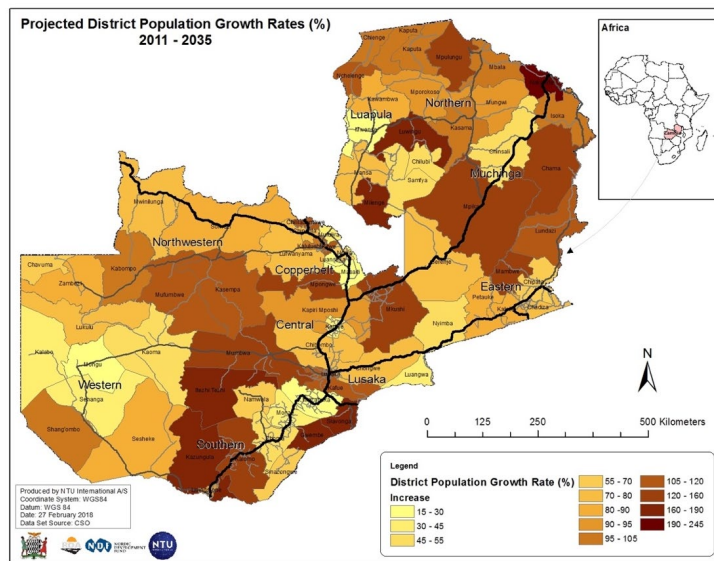
In 2010 Zambia had a population of 13,092,666 that has increased by approximately 32% since the previous decadal census in 2000 and is expected to grow to around 18 million by 2020 and 27 million by 2035. This growth (2.8%/annum) is one of the fastest rates in sub-Saharan Africa and increased from the previous decadal growth rate (2.4%).

The provincial distribution of population density generally follows a similar pattern to provincial population, with Lusaka and Copperbelt Provinces each having populations of around 2 million and densities of 60-100 persons/km<sup>2</sup>. The less populated Western, North-Western and Muchinga Provinces have provincial populations of around 1 million and densities of only 6-8 persons/km<sup>2</sup>. Figure 25 illustrates that there is a close correlation between main road corridors, urban centres and population densities. The Mozambique, Malawi and DRC borders illustrate the importance of cross-border influences. Figure 26 shows the key centres of population growth by district.



**Figure 25: 2010 population densities by district and constituency**

Source: Central Statistical Office 2010 Census on Population and Housing



**Figure 26: Projected district population growth rates 2011-2035**

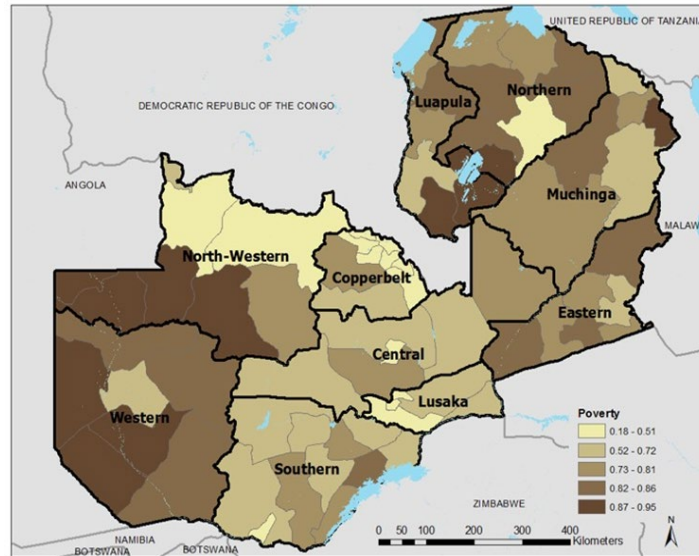
Source: CSO, Zambia Population and Demographic Projections, 2011-2035

#### 4.5.2 Urban populations and growth

Zambia has over 42% of the population living in urban areas. That is expected to rise to 46% by 2035. Zambia’s major centres are already experiencing severe congestion at peak times and increased urbanisation will require new consideration of decongestion, public and non-motorised transport, pedestrianisation and vehicle emissions reduction strategies to sustain unhindered flows through these cities.

### 4.5.3 Livelihoods, poverty and vulnerable groups

A large proportion of Zambia's population (54.5%) lives below the national poverty line. 40.8% of these are considered to be in extreme poverty. Figure 27 shows the distribution of poverty by district, illustrating the close correlation between extreme remoteness, poor access and high poverty, particularly in western and northern Zambia. Road access has a high criticality value for poverty reduction in these areas.



**Figure 27: Distribution of poverty by district, 2015**

Source: Central Statistical Office of Zambia. 2015. Living Conditions Monitoring Survey.

## 4.6 Accessibility

### 4.6.1 Planning frameworks

Zambia's landlocked position makes it heavily dependent on its external and internal transport networks for international and regional links. Of all the modes of transport (road, rail, air, water) about 80% of people and goods are transported by road, being generally the fastest and most reliable mode of transportation (Table 2).

National development planning frameworks appreciate this and stress the importance of Zambia having an effective intra- and inter-modal transport network which can serve and distribute the rising volumes of domestic cargo, imports, exports and transiting goods.

The main challenges facing improvement to inter-modal facilities are:

- optimising resource allocations and utilisation levels between the paved roads, the rural networks and the linked water, rail and air transport systems; and
- addressing system improvements, for example, there are continuing delays at border crossings in spite of one-stop-border posts and other trade facilitation agendas.



**Table 2: Tonnage and percentage share of national freight traffic - base and high projections (2016-2037)**

<b>Freight Traffic Mode (mt/day)</b>	<b>2016</b>	<b>2037 Baseline</b>	<b>2037 High</b>
Road	117,009	226,035	192,377
Rail	13,139	15,062	48,719
Air	132	323	323
<b>Total</b>	<b>130,554</b>	<b>241,925</b>	<b>241,925</b>
<b>Freight Traffic Mode (%)</b>			
Road	89.6%	93.4%	79.5%
Rail	10.1%	6.2%	20.1%
Air	0.1%	0.1%	0.1%

Source: *Zambia National Transportation Master Plan Ministry of Transport and Communications, 2017, p. 31*

Given that production of goods, including imports and exports, is expected to more than double in the 20 years to 2037, the transfer of freight cargo traffic to railways would offer trunk road maintenance costs and climate risks, as well as GHG emissions reductions and trip optimisation. Intermodal haulage could still utilise medium cost/short distance trips by road, while continuing the low cost of long-distance trips via railways.<sup>19</sup>

#### **4.6.2 Air transport intra- and inter-modal hubs**

Air transport is still relatively underdeveloped in Zambia away from its five international airports: in Lusaka, Ndola, Kasama, Livingstone and Mfuwe. Even these airports carry relatively insignificant domestic passenger and cargo loads but in future will have much greater importance. Good road access to airports is an essential pre-requisite.

#### **4.6.3 Waterway inter-modal linkages**

The large lakes (Tanganyika, Mweru, Bangweulu, Kariba), navigable rivers and swamp channels and associated waterways (about 2,250 km) offer considerable opportunity for enhancing the cost-effective movement of goods and people to Zambia's rural areas. Zambia's principal port of Mpulungu has major potential to contribute to regional trade by strengthening trade flows between the Great Lakes and North-South Corridors.

Limited utilisation is due to poor handling equipment at harbours, inadequate dredging facilities and poor market linkages. Climate change may have greater impacts on water transport than on road or rail transport.

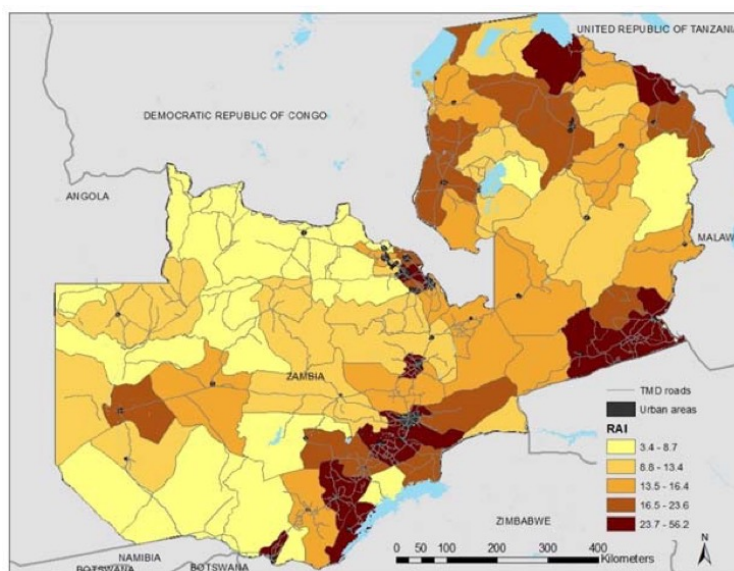
#### **4.6.4 Road access indices**

The three most important considerations in the prioritization of rural road connectivity are accessibility, local productivity and poverty alleviation. Yet less than 50 km of the rural road network is paved and the rest is constructed to earth and gravel wearing course

<sup>19</sup> GRZ, 2017. *Op. cit.*

standards. The Rural Access Index (RAI)<sup>20</sup> is Target 9.1 of the Sustainable Development Goals (SDG) and estimates that although 70% of Zambians depend on agriculture for their livelihood, only 17% live within 2 kilometres of an all-season road — about half the African average<sup>21</sup>. About 7 million people are still left largely unconnected to the road network.<sup>22</sup> The RAI is generally high (good accessibility) in the Lusaka and Copperbelt Provinces, but low elsewhere.

A comparison of Figure 27 and Figure 28 below shows a close correlation between high poverty and low rural accessibility, measured by the RAI. Low rural road access contributes to limited delivery of commercial services and to under-performing markets, schools and health centres. Connectivity down the hierarchy of the road network is essential, not least to support small-scale agricultural and livestock production. Tellingly, the average distance to a market is estimated at 20.9 km in rural areas and 3.4 km in urban areas.<sup>23</sup>



**Figure 28: Rural Access Index estimates at district level - 2016**

Source: World Bank, 2016

## 4.7 Environmental factors in road sector criticality

### 4.7.1 Vulnerable landscapes, ecosystems and drainage systems

Road access is vital to human development, but roads can have large negative environmental influences, inter alia habitat fragmentation and encroachment, increase wildlife road kills and interrupted ecological systems. These outcomes tend to be increasing, cumulative and long term. Human encroachment in Game Management Areas

<sup>20</sup> The RAI indicator is the share of the population who live within 2 km of the nearest road in “good or fair condition” in rural areas. A road in good condition refers to: i) Paved road with IRI less than 6 meters/km and unpaved road with IRI less than 13 meters/km, when IRI data are available; ii) Paved road in excellent, good, or fair condition and iii) Unpaved road in excellent or good condition, when IRI data are not available but other road condition data, such as the visual assessment are available.

<sup>21</sup> KPMG International. 2013. *Zambia Country Mining Guide*. p. 14.

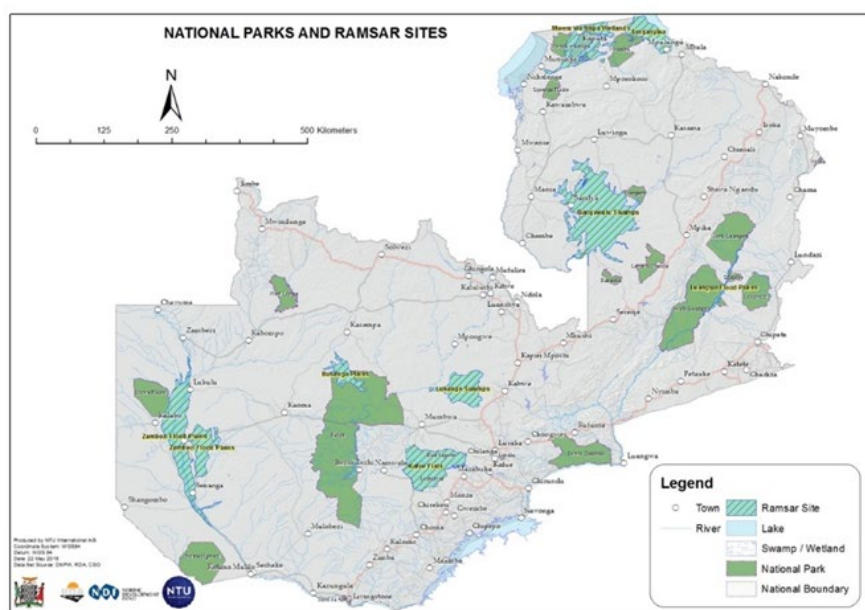
<sup>22</sup> Limi, A. and Gericke, B. 2017. *Op. cit.*

<sup>23</sup> Limi, A. & Gericke, B. 2017. *Op. cit.*

(GMAs) and national parks for example, is generally advancing outwards from main roads towards national parks at a rate of up to 2 km per year.<sup>24</sup>

Zambia's biodiversity is managed mainly within a network of wildlife, forest and heritage protected areas and these call for special consideration in road network criticality assessments, although productivity from many wildlife and forestry protected remains well below optimum levels (Figure 29).

The 20 national parks cover close to 8% of the total land area; 36 Game Management Area (GMAs) cover a further 23% of total land area); and 8 Ramsar provide additional coverage in wetland areas. Zambia has more than 450 national and local forest reserves that are managed by the Forestry Department and there are numerous national heritage sites (archaeological sites, cave paintings, cultural relicts) that are managed by the National Heritage Conservation Commission (NHCC).



**Figure 29: Zambia's National Parks and Ramsar Sites**

Source: [www.unesco.org](http://www.unesco.org)

<sup>24</sup> Lindsey PA, Nyirenda VR, Barnes JJ, Becker MS, McRobb R, et al. 2014. Underperformance of African Protected Area Networks and the Case for New Conservation Models: Insights from Zambia. *PLoS ONE* 9(5): e94109. doi:10.1371/journal.pone.0094109

## 5. Vulnerability Factors in Zambia's Road Transport Sector

### 5.1 Economic factors impacting on Zambia's road transport sector vulnerability

The nature of climate impacts on Zambia's infrastructure, economy and its people in the future will be closely linked to the responsiveness of economic policies and to current and projected economic performance. Put simply, more available funds can make for a better and more resilient road transport network.

Analysis of the long term economic trends show that despite the annual average growth in 3.2% in GDP since 1960, the GDP per capita has remained virtually unchanged over that period, growing from US\$ 1,508 to US\$ 1,626 (at 2010 constant prices) growing at 0.1%. Thus, growth in the economy has not been reflected in improved livelihoods, due mainly to strong population growth (averaging 3.1% per year in the 5 decades since 1964). Notably, the Gini Coefficient<sup>25</sup> has increased from 0.65 to 0.69 in the last five years, suggesting that income distribution is deteriorating<sup>26</sup>.

More positively, real GDP growth averaged roughly 6.6% per annum in the past decade, though this has slowed recently. Dynamic analysis of the GDP's structure also indicates some deepening of the economy. In 2010, the primary sector accounted for 23.5% of GDP, the secondary sector for 20.6%, and the tertiary sector for 55.9%, but by 2015 the corresponding proportions were 18.6%, 22.0% and 59.4% respectively.

But many serious economic problems remain, particularly with the persistent budget deficit, balance of payments difficulties and rapidly growing external and domestic debt. These considerations suggest that the country's short-term ability to invest in necessary climate resilient improvements to its road network and access in rural areas will be constrained and this will diminish prospects for economic growth and livelihoods improvements.

### 5.2 Construction and maintenance factors in road infrastructure vulnerability

Funding for road development, rehabilitation, and maintenance is from different sources, through the National Road Fund Agency (NRFA) to the respective road agencies. In the period 2011-2015, the government spent around 2.2% of GDP on road development and maintenance, 20% of which was financed out of road user charges. More than 50% of this was spent on road construction and rehabilitation. In contrast, until recently, funding for

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<sup>25</sup> *The Gini Coefficient is a measure of statistical dispersion intended to represent the income or wealth distribution of a nation's residents and is the most commonly used measurement of inequality.*

<sup>26</sup> *Innocent Shampande. 2018. Op. cit. <http://documents.worldbank.org/curated/en/436381519914536339/Zambia-AFRICA-P159330-Zambia-Improved-Rural-Connectivity-Project-Procurement-Plan>*

road maintenance, particularly for the feeder road network, has been irregular and inadequate.

For the Trunk, Main and District (TMD) network, there is now a generally increasing trend in investment in routine maintenance from a low of 4% of road sector budgets in 2013 to 69% in 2016 (of which 24% was for periodic maintenance). In contrast, the share of maintenance budget for the PFR has been on the decline, with a strong reduction in road expenditure in 2016 (33% less than 2015).

In awareness of foregone rural economic development opportunities, the new Road Maintenance Strategy (RMS) 2015-24 deliberately now focuses on the neglected PFR network. The mechanism being used is the roll-out of Output and Performance-based Road Contracts (OPRC), which targets a reduction in the proportion of poor roads from 84% to 30% by 2024.

National budgetary constraints may, nevertheless, limit the effectiveness of this programme in the immediate future.

### 5.3 Physical and ecological contributions to road sector vulnerability

Topography, geology and soils are important factors that contribute to the vulnerability of road infrastructure to climate and climate change impacts. Associated impact vectors include but are not limited to: precipitation, propensity to flood, levels of use, and operational characteristics. In general terms altitude and rainfall in Zambia increase from South to North, from agro-ecological Zone I to Zone III. And average temperatures decrease from the hot valleys of agro-ecological Zone I to the moderate plateau and upland areas of Zones II and III.

Areas in Zambia that are particularly vulnerable to heat, runoff and slope stability topographic impacts include: the dissected, steep slope terrain of the rift valley escarpments; dambo<sup>27</sup> areas, and floodplains of all the major rivers (the Zambezi, Kafue, Luangwa and Chambeshi/Luapula and associated swamps). Gently undulating areas along the Zambia's western border with Angola and Namibia – the Barotse Flood Plain – are dominated by deep, unconsolidated sandy soils and are also subject to extensive annual flooding.

### 5.4 Policy, institutional and planning issues

The National Climate Change Response Strategy (NCCRS), introduced in 2010, provided a framework for coordinating all climate change activities in the country until the adoption of the National Climate Change Policy (NCCP) in 2017. However, climate change issues are still being addressed in a fragmented manner using various sectoral policies, strategies and plans, and these have had limited overall effect. For example, the RDA has its own Climate Resilient Roads Strategy (CRRS) that is not entirely consistent with the NCCP and the findings of this CVA. The National Transport Policy, approved in Parliament in 2018,

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<sup>27</sup> *Headwater grasslands that are seasonally saturated but carry subsurface flow through the year.*

and the National Transport Master Plan have practically no coverage of climate change or resilience at all.

Overcoming the current fragmentation of efforts will require much greater determination and collaboration by all stakeholders, particularly to enhance information flows, ensure collaborative data sharing, and to mainstream climate change into policies and implementation strategies within and across sectors.

Evidence from around the world indicates that one of the most significant factors behind actions to address climate change is a lack of political will. This is often at least partly the result of inadequate conclusive information. Therefore, strengthening the flow of usable climate information to national decision makers is probably the most important requirement of any climate mitigation and adaptation strategy.

At the road sector level institutional difficulties also exist. The three principle road sector institutions RDA, NRFA, Road Transport Safety Agency [RTSA]), and numerous Local Road Authorities (LRA) each respond to one of six different line ministries (Ministry of Housing and Infrastructure Development [MHID], Ministry of Finance [MoF], Ministry of Transport and Communication [MTC], Ministry of Local Government [MLG]), Ministry of Tourism and the Arts (MTA) and Ministry of Defence. Other supporting institutions either provide inputs to the road transport sector or assisting in the cooperation between the major institutions. Compounding this diversity, a number of ministries have recently changed, and roles and responsibilities are still being clarified.

## **5.5 Inadequate data for effective climate-related decision-making**

Conducting a climate vulnerability assessment of the road transport sector in Zambia presents challenges on a number of fronts: the scarcity of reliable data, and deficiencies in data system inter-operability among different stakeholders being the most important. Of primary concern is an absence of a culture of communication and collaboration with and between users and stakeholders. Thus, there is also a reluctance to share data even when it is available, despite it being central and strategic to coordinated action. This limits the effectiveness of decision-makers and stakeholders.

Specific challenges include the paucity of primary, digital format, observed climate and hydrological data for Zambia. There is a considerable volume of historical climate and hydrological records, many with long data sets, but most of these data still remain in hard copy format. This limits analysis, particularly of historical trends and future projections, and places greater reliance on merged, remotely sensed and re-analysed data products. There are also systems and skills capacity limitations impeding the generation and interpretation of robust climate information, as does the absence of a robust system for linking climatological and hydrological information systems.

## **5.6 Priority vulnerabilities in the road transport sector**

The climate sensitivity of roads, which is their predisposition to be adversely affected by weather and climate related hazards, is defined by the road asset's design criteria, construction quality and current condition, the maintenance regime, and the use and

operational characteristics that have a direct bearing on defining its sensitivity. For example, some parts of a network form major links and therefore may cause a higher level of disruption if damaged in extreme weather events. Other locations may have poor access and/or weak transportation linkages that could be further exacerbated by extreme weather events.

Intense precipitation and longer periods of sustained precipitation have the most pronounced effect on road infrastructure through flooding; the flash runoff destruction of road pavements, bridges, and culverts; or slopes failures and landslides onto roads and bridges. Temperature and humidity increases will raise the potential for asphalt deterioration through increased oxidation, aggregate spalling, rutting, and lateral displacement of asphalt under traffic loading. Prolonged dry spells can lead to decreased soil humidity resulting in road base deterioration and loss of bearing capacity – all of which can accelerate the deterioration of roads.

As already noted, the most complete recent road condition survey of 2015 indicated that 60% of the CRN requires major rehabilitation and only 40% is in a maintainable condition. Within the CRN about half of the TMD road network is in good or fair condition, whereas the PFR network (which extends from District roads and are mostly unpaved) are almost all in poor condition. Unpaved, poorly maintained roads are the most sensitive to all climatic events and especially washouts and flooding.

Trunk roads are the most critical part of the road network because of traffic volumes, the value of goods and services being transported, and their function in the eastern and southern African regional highway system. The high percentage of heavy vehicles on Zambia's Trunk and Main road system (30% of volume) is a significant structural stressor on the roads, especially between the mines in Copperbelt Province and along the regional transit routes. While well maintained on the whole, the historical impact of damage to Trunk and Main roads and bridges from climate events (washaways, flooding, landslides) has been costly in both direct and indirect costs (see below). A recent report on climate-related damage to the road network<sup>28</sup>, indicated a close correlation between rainfall intensity and road asset damage.

Vulnerability resulting from location – the combination of exposure to climate related hazards (such as flooding and high temperatures) and geographic sensitivities (geology and soils, topography and water bodies) – is most evident in the following areas:

- the valley areas of the Luano, Luangwa, mid-Zambezi and Luapula;
- the Zambezi escarpment south of Kafue, the Luangwa escarpment between Rufunsa and Nyimba on the T2 and the Mpulungu escarpment on Lake Tanganyika;
- the upper Zambezi valley, especially between Kazungula and Sesheke;
- the Mafinga Hills in north-east Zambia;
- the Ikelenge Pedicle in north-west Zambia; and
- flood plains, especially the Kafue Flats and the Barotse flood plains.

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<sup>28</sup> RDA. 2017. *Bridge and Emergencies Unit Report*

Many minor bridges and culverts are regularly swept away during times of flood, cutting off large areas of Zambia. By way of example, the widespread floods of 2007 affected 75 districts (of the total of 110), and Disaster Management and Monitoring Unit (DMMU) reports indicate that in 39 of these districts 66% of the roads, bridges and culverts were either washed away or damaged.

An inventory of high-risk economic areas in Zambia was conducted as part of this CVA. A filtering process was used, firstly identifying roads of social-economic importance. Secondly, a three-variable multivariate analysis was carried out.

The variables applied were:

- areas with high geographical sensitivity and exposure;
- road network sensitivity to structural characteristics and road condition; and
- traffic volumes.

The analysis applied to areas of socio-economic importance, indicates the following districts are the most vulnerable, and hence the districts with road infrastructure most at risk (Table 3).

**Table 3: Climate-vulnerable Districts in Zambia**

Province	Districts
Northern Province	Kasama, Nakonde
Muchinga Province	Isoka, Chinsali, Shiwa Ng'andu, Mpika, Chama
Central Province	Serenje, Mkushi, Mumbwa, Kapiri Mposhi and Kabwe
Luapula Province	Nchelenge, Kawambwa, Mansa, Mwansabombwe, Samfya, Chembe
Copperbelt Province	Mufulira, Kitwe, Ndola, Chingola, Luanshya, Masaiti, Mpongwe
Eastern Province	Mambwe, Chipata, Katete, Ludanzi and Nyimba
Lusaka Province	Chirundu, Rufunsa, Kafue, Chongwe and Lusaka
Northern-Western Province	Kasempa, Solwezi, Mwinilunga and Ikelenge
Western Province	Kaoma, Mongu, Senanga, Sesheke
Southern Province	Sinazongwe, Monze, Mazabuka, Choma, Siavonga

A number of critical river crossings and route sectors have also been identified where route redundancy consideration is required. Table 4 shows climate-impact-at-risk road sectors warranting detailed risk assessments.

**Table 4: Climate-vulnerable river crossings in the Core Road Network**

Road Sector	Climate-vulnerable areas
T1 Livingstone-Lusaka	Kaleya River bridge, Munali Pass
T2 Chirundu-Lusaka	Several escarpment rivers, the escarpment slopes, Kafue River bridge
T2 Lusaka-Kapiri Mposhi	Lusaka central (flooding), Mulungushi River bridge



T3 Kapiri Mposhi-Kasumbalesa	Kafulafuta River and Kafue River (2) bridges
T4 Lusaka-Chipata-Malawi	Luangwa escarpment, Luangwa River bridge, Nyimba and Lutembwe River bridges
T5 Chingola-Solwezi-Mwinilunga-Jimbe	Lunga River (2), Lufubwa, Mutanda, Mwombeszhi, Kabompo and West Lunga River bridges and the Zambezi River
M1/M2 Mpika-Kasama-Mbala-Mpulungu	Chambeshi River bridge and Lunzua River bridge and the Mpulungu escarpment
M3 Mansa-Luwingu- Kasama	Lufubu, Lubasenshi and Lunga River bridges
D235 Serenje-Samfya	Luapula River bridge
M8 Mutanda-Mufumbwe	Kabompo, Kawilo and Makondo River bridges and floodrisk in the Lukunyi area
M9 Lusaka-Mumbwa- Kaoma-Mongu-Kalabo	Mwembeshi River bridge, Kafue River bridge, Zambezi River bridge and floodplain
M10 Mongu-Sioma- Sesheke-Kazungula- Livingstone	Zambezi River (2) bridges and flood risk in the Kazungula area
M11 Choma-Chitongo-Namwala-Kafue pontoon	Ngongo and Munyeke River bridges and the Naminwe floodplain to Namwala and the Kafue pontoon
M12 Chipata-Lundazi	Lumezi and Lunzi River bridges

Key inter-modal and intra-modal connections that are identified by this climate vulnerability analysis are shown in Table 5.

**Table 5: Key Inter-modal and Intra-modal Links in the Core Road Network**

<b>Inter-modal Links</b>	<b>Locations</b>
Rail-road-air	Lusaka, Ndola, Livingstone
Road-rail	Kapiri Mposhi, Lusaka, Ndola, Kitwe, Chingola, Mkushi, Kasama, Batoka, Chipata
Road-water	Mpulungu, Nchelenge, Samfya, Mongu, Siavonga
<b>Intra-modal</b>	<b>Locations</b>
Rail-rail	Kapiri Mposhi, Kitwe
Road-road	Kazungula, Livingstone, Choma, Chirundu, Lusaka, Chipata, Kapiri Mposhi, Ndola, Kitwe, Chingola, Kasumbalesa, Mkushi, Mpika, Kasama, Nakonde

Zambia is still largely an import-dependent economy, but with high value, albeit mostly unprocessed, exports. It is, therefore, heavily dependent on its regional transport network connecting it to various export and import destinations. Overall, most transportation infrastructure, with the exception of some Trunk roads and Lusaka's international airport, are in some state of disrepair.<sup>29</sup> About 80% of people and goods are currently moved by road as it is the fastest and most reliable mode of transportation; the railway network is currently carrying an estimated 12% of freight.

This highlights the importance of Zambia having a more balanced and sustainable transport system with robust intra- and inter-modal connectivity, more route redundancy and less reliance on road transport. These are priorities recognized in the 7NDP, which

<sup>29</sup> GRZ, 2017. *Zambia National Transportation Master Plan*, Ministry of Transport and Communications, Lusaka

states the determination of Government ‘to deliver improved transport infrastructure within the four modes of transportation to grow the economy and improve socio-economic opportunities across the country.’

Optimum development of the transport system will require sustainable approaches based on maximising the comparative advantages of each transport mode. Flexible transport modes and efficient inter-modal linkages and transfer facilities will also strengthen Zambia’s capacity to adapt to climate variability and change. Four factors are paramount:

- 1) prioritisation of road to rail intermodal hubs - the road sub-sector is carrying an excessively large share of the freight haulage business, resulting in incremental congestion and damage to roads;
- 2) road to water hubs that expand international trade and are climate resilient and often cheaper modes of transportation;
- 3) waterway transportation for communities in rural areas is important for improving access. Given the sensitivity of poor rural roads to flooding, and also the impacts of drought on transportation in canals and swamps, the latter warrants particular attention; and
- 4) road to air linkages at all levels, without which air transport growth options are constrained.

## 6. The economic costs of climate-related damage to Zambia's road infrastructure

### 6.1 Direct costs of climate impacts

This climate vulnerability assessment has delivered a first attempt to quantify the historical cost of climate-related impacts on Zambia's road transport sector. The underlying assumption is that for both new construction and maintenance and rehabilitation, the objective is to retain the design life of the investment.

The cost estimates for maintenance differ between paved, and unpaved gravel, and earth roads. For all roads, an approach is adopted that bases the cost of maintenance on the cost of preventing a reduction in design life (that may come from immediate, or delayed incremental damage, or from indirect costs). The implementation of this approach involves two basic steps (that cover both new construction and maintenance):

- estimating the design life reduction that would result from a unit change in climate stress; and
- estimating the costs of avoiding that reduction in design life.

The methodology used adopted the simplifying assumption that the design life reduction is equal to the percent change in climate stress, scaled for the stressors' impacts (mainly extreme rainfall and flooding and extreme temperature and drying effects) on maintenance costs. Calculating flood impacts is more complex because of the need to define the damage and damaged area accurately.

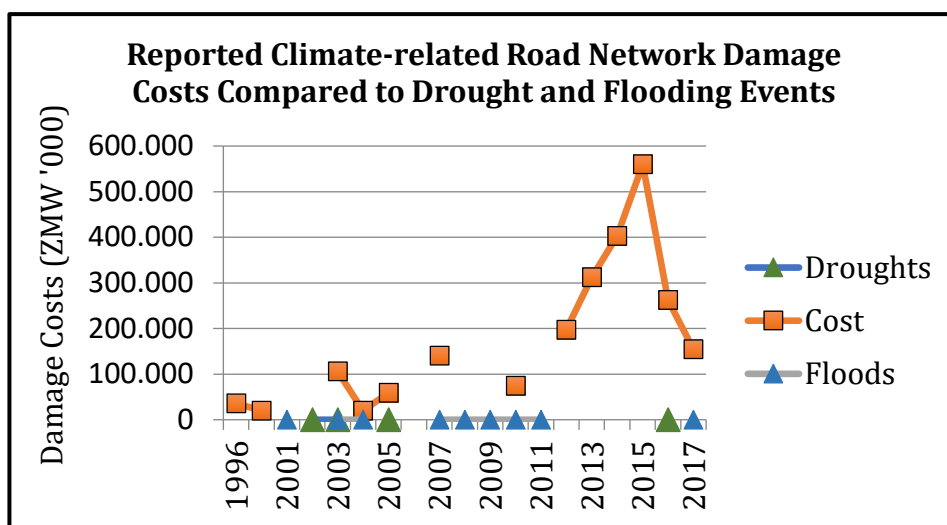
Historical RDA data were examined first and unfortunately, the available base data are incompatible with a complex analysis – they have not been systematically collected and they are often incomplete (the most common recorded damage has been washaways to culverts, vented drifts and minor bridges). Nevertheless, the more reliable and complete data sets are available for the six years between 2012 to 2017. These data are only rainfall-related but in the absence of other options were used as a base for the economic analysis for the period 1996 to 2017.

The results indicated that the long-term cost of damage to road infrastructure from the direct impact of rainfall over the period **1996 to 2017** is an **estimated ZMW 2.345 billion (approximately US\$ 23 million) in 2017 constant prices (an average annual impact cost of ZMW 107 million)**. Within this estimate approximately 29% of the costs accrued from the paved network and the much greater percentage (71%) from the unpaved (mainly rural) network.

Efforts to disaggregate climate-related damage to the road network relied on the more accurate RDA Regional Office (RO) records from 2012. These historical data indicated an average total annual, direct cost of all climate damage for that year to the road network of **ZMW 298 million**, roughly three times the 22-year average to 2017.

Although it is difficult to disaggregate real climate damage from poor design, construction and maintenance, even this figure is likely to be an underestimation because of data shortcomings and non-systematic data recording. That is corroborated by an RDA estimation for the specific rainfall-only related cost of damage over the very high rainfall season of 2016/2017 of **ZMW 208 million**. As that 2017 RDA report indicated that rainfall/flooding damage was responsible for 48% of the total impact of climate stressors, an average annual direct cost estimate for gross climate damage of **ZMW 433 million (US\$ 43 million)** may be more realistic. More than 80% of these costs come from the wetter northern part of the country (North-western, Copperbelt, Luapula, Northern, Muchinga Provinces).

But major data inputs shortcomings remain as shown in the poor correlation of reported road damage costs with known flood and drought years since 1996 (Figure 30).



**Figure 30: Reported Climate-related Road Network Damage Costs Compared to Drought and Flooding Events 1996-2017**

Based only on historical data the unpaved network accrues over 70% of annual climate-related damage. However, the unit cost of paved road damage at some ZMW 63,000/km, is understandably approximately three times higher than that for unpaved roads.

## 6.2 Indirect and total social costs

The economic analysis also attempted to calculate the indirect, social costs of climate damage, recognising that together, the wide array of indirect economic and social costs are likely to be higher than direct costs. Indirect costs were classified into three categories:

- 1) increasing transport costs: due to reduced or complete inaccessibility from a damaged road link;
- 2) economic activities: (mainly agricultural, mining and some industrial but also tourism) affected by interrupted, or no accessibility;
- 3) accessibility to social services: (mainly education and health) is reduced or prevented by road link damage.

For reasons of information availability, the social, indirect costs of climate stressors on the road network were calculated based **only** on a) transport vehicle operating cost (VOC) and b) time cost (VoT) data, using information from the six main Trunk roads as a proxy. There were insufficient data to calculate the indirect impacts on economic productivity and social service delivery.

These VOC and VoT results were combined and the indirect costs for Trunk roads then extrapolated across all road categories (weighted by traffic level and proportional direct cost). The outcome was an estimated average annual social cost of direct and indirect, reported, precipitation-related damage to the road network of **ZMW 235.98 million (about US\$ 23 million)**, comprising **ZMW 148 million in direct** and **ZMW 88 million in indirect costs** (Table 6).

**Table 6: Total Annual Direct and Indirect Costs of Climate Damage to the Zambian Road Network (ZMW millions)**

Cost Type	Provinces	Trunk	Main	District	Urban	Other	Total
<i>Direct costs</i>	Central	752	100	2,478	1,067	1,385	5,781
	Copperbelt	142	375	16,969	52,733	13,809	84,028
	Eastern	74	43	55	52	416	640
	Luapula	-	341	1,733	210	1,616	3,901
	Lusaka	1,042	56	820	845	226	2,989
	Muchinga	8,428	1,033	1,004	-	376	10,841
	North-	223	16	159	83	53	533
	Northern	-	4,500	10,466	1,726	18,518	35,209
	Southern	-	174	1,403	305	534	2,417
	Western	-	50	1,415	-	194	1,658
	<b>Total</b>	<b>10,661</b>	<b>6,688</b>	<b>36,502</b>	<b>57,021</b>	<b>37,127</b>	<b>147,997</b>
<i>Indirect costs</i>	Traffic level	3,389	883	393			<b>4,665</b>
	<b>Cost</b>	<b>44,788</b>	<b>7,321</b>	<b>17,785</b>		<b>18,090</b>	<b>87,983</b>
<b>Total Cost</b>		<b>55,449</b>	<b>14,009</b>	<b>54,287</b>	<b>57,021</b>	<b>55,217</b>	<b>235,983</b>

It is stressed that these costs are calculated from the extrapolation of damage based on Trunk road VOC/VoT data and are shown only to illustrate the relative proportion of direct (63%) and indirect (37%) costs derived by this methodology. The conviction remains that with more data a higher proportion of total damage costs will be found to be contributed by indirect costs.

### 6.3 Projected future climate-related costs of damage to the road network

While historical patterns of climate-related damage to the road network provide useful baseline information, the rate of climate change demands that projected future impacts are also modelled to identify future trends and associated risks. As there was an insufficient reliable breakdown of historical temperature and rainfall related damage, the mean annual costs of damage were used as a base.

The proxy for the estimation of temperature-related social cost impacts was the need to replace existing asphalt pavements by 2030 with modified asphalt designs to withstand

the effects of increasing temperature. The calculation assumed an annual average 200 km length of new and upgraded road and 300 km of annual routine maintenance. The additional annual cost to these hypothetical sectors of the transition from conventional to modified asphalt is an **estimated ZMW 84.945 million**.

This baseline cost was then applied to global climate model temperature projections for Zambia to 2030 and 2060 for the A2, A1B and B1 scenarios and modelled both for the annual position and the four seasonal periods. All show incremental temperature increases. The median annual temperature-related costs for the A1B scenario for 2030 and 2060 were **ZMW 90.9 million** and **ZMW 98.5 million**, respectively, with maximum projected costs of **ZMW 93.0 million** in September, October, November 2030 season, rising to **ZMW 100.1 million** in the June, July, August 2060 season.

Future rainfall trends in Zambia are less certain. Thus the projected costs of precipitation-related damage were calculated from an annual average social (direct and indirect) base cost of **ZMW 235.98 million** with damage split 90% within the high rainfall months of December, January, February (DJF) and the balance of 10% in the end-of-season months of March, April, May (MAM). For simplicity the other two seasons were given zero values. Projected precipitation trends reviewed the A2, A1B and B1 GCM scenarios and produced median A1B DJF season damage costs of **ZMW 214.5 million** in both 2030 and 2060 (i.e. no increasing trend), and median A1B MAM season costs of **ZMW 23.4 million** and **ZMW 24.1 million** in 2030 and 2060, respectively. Total average annual median A1B costs of precipitation-related road network damage are **ZMW 237.9 million** in 2030 and **ZMW 238.6 million** in 2060.

Using RDA Regional Office (RO) records and the social cost base of ZMW 235.98 million, the summarised projected average annual costs of climate-related damage (temperature and rainfall) to the Zambian road network was estimated at **ZMW 328.8 million (US\$ 33 million)** in 2030 and **ZMW 337.1 million in 2060**, with the largest increment in climate-related damage cost in the first period to 2030.

Given the gaps and uncertainties in the various road condition and climate data bases these preliminary cost figures should be used cautiously. As noted earlier, a simple extrapolation of rainfall-related damage costs alone, produced a total current annual direct climate impact cost estimate of **ZMW 433 million (US\$ 43 million)**.

In the region, Zambia is particularly vulnerable to climate impacts due to the relative length of its road network. Based on this reality, regional studies examined during this CVA estimate much higher future costs of climate-related damage to Zambia's road network, increasing to an annual average cost of **US\$ 772 million** by 2050 (without adaptation).<sup>30</sup> However, given its extensive unpaved road network, Zambia could generate short-term average annual maintenance savings of up to **US\$ 193 million** by using adaptive approaches.<sup>31</sup> Of note though in that study, the full benefits of adaptation only become evident after 2030 because of discounting and lag effects.

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<sup>30</sup> Paul S. Chinowsky, Amy E. Schweikert, Niko L. Strzepak, Ken Strzepak, May, 2015: *Infrastructure and climate change: a study of impacts and adaptations in Malawi, Mozambique, and Zambia*, Climate Change, Volume 130, Issue 1, pp 49–62.

<sup>31</sup> *Ibid.*

## 7. Adaptation and mitigation options

This climate vulnerability assessment has demonstrated that increase in climate variability and change are on-going realities. Accumulating evidence suggests that the long-term effects of climate change will have direct and indirect impacts that are almost certain to be wider and more extreme in their effects than those experienced thus far (although there may also be positive impacts). Current data goes further and indicates that without imminent slowing of GHG emissions, tropical Africa will be significantly negatively impacted. Zambia's mid-continental position may exacerbate that situation.

### 7.1 Adaptation and the project cycle

The relatively long design life of road transport infrastructure means that road systems designed today will need to be able to resist climatic stressors and extremes 20 or 50 years hence. In view of the projected costs of climate damage outlined earlier, climate resilient road transport sector adaptation and mitigation measures could have significant, positive economic benefits going forward. These measures need to be incorporated into the full project cycle, including feasibility, design, procurement, construction and maintenance but is a complex issue warranting detailed cost-benefit analysis.

### 7.2 The World Bank four pillars approach

This CVA Report followed an adaptation and mitigation approach that considers the World Bank "four pillars" structure for integrating climate change into road asset management and applies the Zambia Climate Proofing Manual<sup>32</sup> approach. These differentiate "soft" (institutional and information platforms) from "hard" (changes to designs and procedures) adaptation measures. It then places them in a process structure examining in turn:

- 1) policy and institutional issues - including the setting of monitoring timeframes;
- 2) planning frameworks;
- 3) technical options;
- 4) emergency response systems; and
- 5) monitoring and evaluation.

Adaptive capacity, or the ability for a system to adapt to and/or cope with change is the most significant driver that can be used to reduce road transport network vulnerability. However, an analysis of operational and technical options is important to strengthening adaptive capacity. Of similar importance is the identification of incremental and transformative pathways that reduce the underlying risks of adverse climate impacts as these form the basis for building climate resilience.

Drawing on best practice from multilateral development banks, international road sector organisations, donor organizations and the private sector, the following are key entry

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<sup>32</sup> Global 21 Consulting. 2014. *Integrating Climate Change into Planning and Budgeting Processes in Zambia. Climate Proofing Manual. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.*

points for adaptation solutions that address climate change from multiple angles, including infrastructure, policy and financing.

These entry points will yield the most effective results if they form part of a logical continuum:

- incorporating climate change into transport policies;
- using climate-sensitive policies to develop plans, legislation and budgeting;
- incorporating climate risk screening into infrastructure planning, procurement and implementation processes;
- improving the collection of data for decision making and updating design standards;
- introducing climate-resilient road infrastructure solutions;
- improving network management options, including network redundancy;
- improving the inclusiveness and integration of networks;
- improving road infrastructure maintenance;
- where appropriate considering cost/benefit-based options for labour-based methods, especially for rural roads;
- incorporating climate-related material into environmental and social impact assessments of road works;
- increase access to international financing to climate-proof infrastructure or mitigate risk.

Where possible climate resilient solutions should follow a holistic approach that incorporates innovation into both mitigation (for example, reducing indirect and direct road sector GHG emissions) and technical and operational adaptation solutions.

An important consideration is that investments in road sector adaptation may be heavily front-loaded, so detailed time-linked analysis of likely scenarios, associated risks and benefits and general developmental objectives, will be essential to optimum decision making. The availability of robust input data is clearly an essential prerequisite.



## 8. Training and capacity development

Making meaningful and sustained efforts to strengthen climate resilience in the road transport sector requires inputs at multiple levels from policy to works methodologies. These will all be more effective if accompanied by systematic training programmes as part of the introduction of innovative adaptation and mitigation solutions into institutions and systems. The CVA Report formed the first element of a Project process that has been followed by four other activities: 1) policy review; 2) institutional capacity assessment; 3) technical (engineering) standards revision; and 4) training. These are being applied over the years until mid-2021. The training activity continues through the project period and will assimilate information generated from the other activities and feed it into a continuous training needs assessment and the design of targeted training modules. These modules are biased to RDA but will also be inclusive across the numerous transport sector stakeholders, both within and outside government, including the private sector.

It is stressed that the intensity and inclusiveness of training outside this Project will be instrumental in consolidating and sustaining gains in climate resilient in the road transport sector.

### 8.1 Climate and climate change awareness

Knowledge and information are crucial for climate action. Building capacity and supporting decision-making for effective climate services bridges the gap between climate science, policy and practice for adaptation decision-making and disaster resilience. This process is known as '**climate services**' and is an emerging and increasingly important field.

These CVA findings will be an important contributor; supporting a wider appreciation in the road transport sector of climate variability and change issues and potential impacts and also of the role of 'climate services' in road sector adaptation decision-making and overall climate resilience.

Training is being provided in CVA methodologies, including sensitivity modelling and multi-variate analyses. Risk assessments will be an increasingly important activity, providing the more detailed evaluation of road sector and nodal vulnerabilities. The evaluation of asset criticality and development of prioritisation processes are key inputs. This collated information then permits the development of matching and appropriate adaptation and mitigation measures. Institutionalising and mainstreaming these processes will be important to securing gains at all levels (local, district, provincial and national).

Hence, central to any road transport sector climate resilience strategy is the availability of institutional structures that are fit to implement it, and are provided with the necessary technical, human and financial resources. Institutional scorecard assessments forms part of an interactive evaluation and training process that assesses this Project's progress towards strengthened climate resilient institutions and systems. Robust, systematic and comprehensive data collection systems will be key requirements, both within the road

sector agencies (traffic, road condition and climate damage assessment) and with key information providers such as the Zambia Meteorological Department (ZMD), Water Resource Management Agency (WARMA) [formerly WORD] and Disaster Management and Mitigation Unit (DMMU). Sound information collation, analysis and dissemination systems within and associated with the road transport sector are equally critical to successful climate resilience processes. Successful information dissemination will benefit from formalised (and informal) communication protocols between stakeholders.

## **8.2 Criticality, road condition and traffic inputs to vulnerability assessment**

### **8.2.1 Criticality and prioritisation**

Key inputs to assessing road sector climate vulnerability are definitions of road sector criticality. Road sensitivity and exposure data are then superimposed in order to prioritise resilience activities and decision-making. Training in criticality assessment and prioritisation methodologies will strengthen the implementation of climate vulnerability assessments for the road sector.

### **8.2.2 Modelling multivariate analysis for vulnerability scenarios**

Additional training will be useful for the application of multivariate analysis to climate vulnerability road sector situations. Climate variability and change pose costly impacts in terms of maintenance, repairs and lost connectivity; yet many of these impacts can be mitigated and avoided by pro-active adaptation measures. It is a crucial consideration for protecting current and future infrastructure investments and the economic, social, and other functions they serve.

## **8.3 Policy and planning issues**

The constant review and harmonisation of road transport sector and climate and environmental policies is essential in order to maintain a constant ability to respond to climate threats. Of equal importance is a suite of climate resilient transport sector plans and road sector investment and asset management plans. Training will assist in reinforcing the importance of these issues and their inclusion in sector institutional structures and process. The development of “climate champions” will constitute a part of this initiative.

## 9. Key conclusions and recommendations

### 9.1 The climate impact outlook, options and timeframes

This CVA Summary Report has reviewed global, regional and national studies that all demonstrate that Zambia can expect an increase in climate-related risks to its road transport sector as climate variability and change become more complex and intense. A lack of mitigation and adaptation actions will increase costs to the road network.

The tentative economic assessment of climate impacts on the road network in this report confirms that the costs of inaction will be significant in the medium and longer term, and increase. Adopting a framework for integrating climate change adaptation into road sector planning and asset management will mean that potential loss and damage from climate-related events can be considerably reduced or prevented.

An important element of elaborating an action plan is to define the timeframe. The INDC and national Vision end dates of 2030 would seem to be an appropriate target. This usefully also matches one of the milestones being set by the UNFCCC and IPCC. However, 2030 is only ten years away and will require an accelerated approach if meaningful progress is to be achieved by then.

The long-term effects of climate change will impact on the way that individuals, communities and businesses function. Some hazards may require improved management of the process and planning components of infrastructure development. Others will call for project scale adaptation and mitigation responses. An analysis of options for strengthening adaptive and mitigation capacities, specifically incremental and transformative pathways that change the underlying risks to adverse impacts, must underpin approaches to building climate resilience.

This report identifies adaptation actions that will build a more climate-resilient road transport system, reduce overall vulnerability and developing specific system capacities. These also have application in the wider transport sector context.

Possible action entry points are at all levels and include new visions; sectoral and spatial planning; resilient infrastructure technological solutions; ensuring an enabling environment; and building post-disaster risk and recovery support. Having appropriate and innovative national policies, strategies and action plans will strengthen leadership and direction in climate change adaptation and mitigation.

Mitigation measures should not be overlooked as they form an essential component of an holistic national response framework to climate changes. They also have the potential to reduce the cost of adaptation and are often just good common sense.

#### Next Steps

This climate vulnerability assessment is the lead activity of a four-year programme (2017-2021) funded by the Nordic Development Fund to strengthen climate resilience in the

road transport sector. As such it offers a starting point for process facilitation that can be utilised by all key stakeholders to explore opportunities and innovations. As Figure 31 illustrates, the development of climate resilient road assets and capacity is an incremental lengthy process requiring a timeframe of at least ten years.

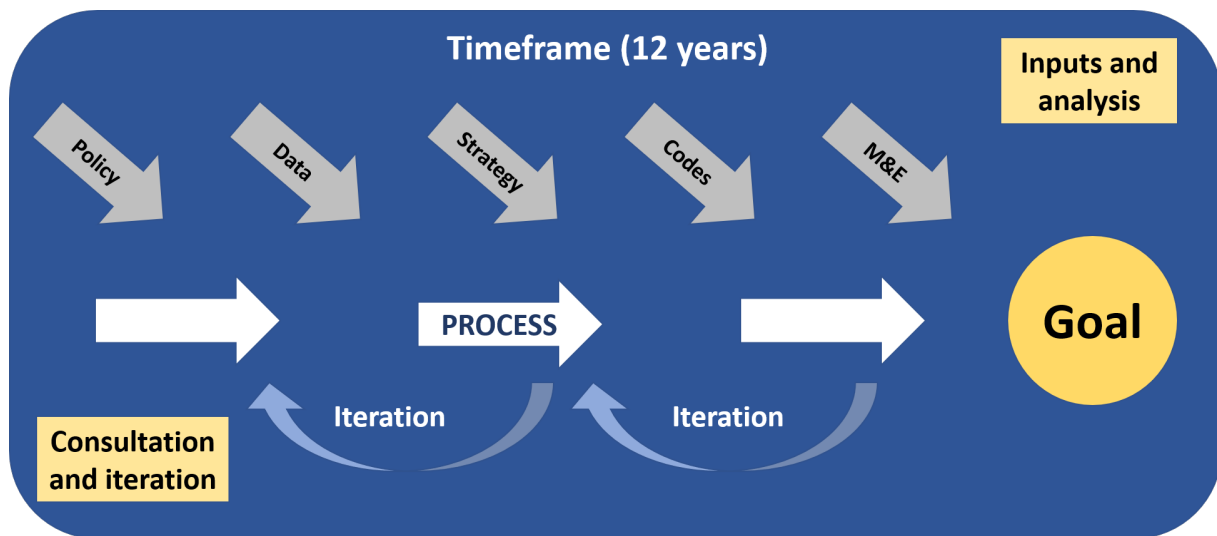


Figure 31: The process to improved climate resilience

Nevertheless, there are four recommended immediate actions that are “low lying fruit”. They include two standardisation actions and two important practical actions:

#### Data Standardisation and Coordination

- Developing a standardised and comprehensive road sector climate data and climate impact data collection, collation, storage analysis, application, reporting and dissemination system. This will significantly enhance management decisions.
- Agreeing and institutionalising standardised planning tools and approaches to climate change responses (for example: the risk management method for roads (RIMAROCC)<sup>33</sup>, the Infrastructure Planning Support System, harmonised road transport costing (HEATCO)<sup>34</sup>, low carbon infrastructure standards and a unified GIS platform for climate-related work). Adopting these standards enables comparison with other efforts and access to valuable global knowledge.

#### Practical issues

- Identifying and implementing agreed technical objectives and outputs for the road transport sector within annual work plans, including improved road condition reporting that integrate and clearly differentiates climate-related condition issues.
- Instituting processes for the regular review and refining of the preliminary road element and node risk assessments that has been achieved under this CVA.

<sup>33</sup> Risk Management for Roads in a Changing Climate (RIMAROCC)

<sup>34</sup> e.g. Harmonised European Approaches to Road Transport Costing and Project Assessment (HEATCO)

## **9.2 Recommendations for policy, planning and institutional issues**

Building on the recent National Policy on Climate Change and the continuing function of the Pilot Programme for Climate Resilience, the CVA has made the following six key recommendations.

### **9.2.1 Climate Policy**

The National Climate Change Policy (April 2016) provides the overall framework for climate-related policy direction. This was not harmonised into the National Transport Policy before that was ratified in 2018, with the consequence that this key and overarching element of transport sector policy still contains no mention of climate resilience. An early review of the Policy is strongly recommended to guide the sector and sub-sector policies.

### **9.2.2 Transport sector planning**

The National Transport Master Plan (2017) still awaits endorsement and application. It sets out a large number of important investments, but these have not been considered from a climate change or climate change strategy context. A further review and up-dating inputs would strengthen the Plan by emphasising its strategic objectives, priorities and implementation path, and identifying critical transport asset vulnerabilities, communities and places at risk. It may also assist in optimising the timing of investments to maximise the return on those investments, particularly from a climate adaptation perspective.

### **9.2.3 Institutional coordination between line ministries**

The road transport sector is currently coordinated through six line ministries. While this is cumbersome, it does reflect practical realities. Nevertheless, effective functioning and coordination of climate resilience solutions demands that more effective and efficient protocols exist for regular horizontal communication between these ministries.

### **9.2.4 An institutional structure for climate coordination within RDA**

It is recommended that a Climate Change Coordination Unit (CCCU) be established in RDA with a GIS platform - realistically probably as an extension of the existing Environmental Unit.

Its objectives should be:

- 1) to establish and implement protocols and systems to build a culture of information collaboration and sharing between the key climate institutional 'Providers' and 'Users' (especially DMMU, ZMD and WARMA-WROD);
- 2) establishing a formal structure for coordinating and responding to climate-related road transport sector disasters that more effectively links RDA and DMMU;
- 3) integrating the unit into road asset management information systems that link the key RDA departments (Planning and Design, Maintenance and Procurement);
- 4) improving road transport network management adaptation options, including strengthened route redundancy and inter- and intra-modal linkages.

### 9.2.5 Mainstream climate change into asset management and practices

It is increasingly important that there is analysis of the relative importance of 'Adapt' and 'No Adapt' approaches to road asset management and their financial and economic implications. It is recommended that RDA:

- Revises operational and maintenance strategies and plans and design and construction/maintenance procurement and contract requirements to include the identification of climate risks and adoption of strategies to limit the impact from climate change, possibly embedding CVAs into the required EIAs (adaptation and mitigation).
- Run appropriate economic analyses of potential adaptation options to assist financial decision making, particularly in conditions where resources are limited.
- Ensure that climate resilience objectives and processes are incorporated into the design of the ROADSIP III programme and the road sector asset investment and management system.

### 9.2.6 Develop more detailed climate risk assessments at a finer spatial scale

This CVA has identified a number of critical points in the road transport network that are particularly vulnerable to severe climate-related impacts. In many of these cases there is also limited route redundancy in the event of a catastrophic failure/closure in a road sector.

Risk assessment is the first step in effective disaster risk management and should be undertaken as part of a comprehensive risk management strategy. This will assist RDA in streamlining their road condition surveys in the future and putting in place maintenance plans and mitigation actions.

## 9.3 Recommendations for improved data management processes

RDA needs to improve the quality, consistency, comprehensiveness and storage of road condition data collection and management, particularly recognise the need to identify climate-related impacts on road condition. Important collateral outputs could include an improved and nationally-standardised GIS system; capacity development for data management; and the coordination and harmonisation of database information systems.

## 9.4 Recommendations for climate resilient road transport infrastructure technological solutions

To be effective, climate resilient infrastructure adaptation and mitigation solutions and technological modifications require inputs at all stages in the project cycle. Planning and design, procurement, construction, maintenance and rehabilitation, should all be involved, together with the environmental and social impacts of road works. Mainstreaming a **climate services** approach will be key to maximising successes. Current developments in whole life and carbon emission reduction methodologies offer promising opportunities. For example, further developments in Building Information Modelling (BIM) have expanded its capabilities from 3-dimensional modelling to include the time dimension to projects and thus also to incorporate cost and carbon data (BIM 5D+).

Coupled with standards such as the British Standards for carbon - PAS 2080, these innovations offer opportunities to set comprehensive, low carbon, climate resilience targets for the road sector.

## **9.5 Recommendations for securing international climate finance: making the case**

Insufficient financial resources exist to support a comprehensive array of climate resilient solutions at the moment. Exploring sources of climate finance options should become a key priority that requires integration into national, sectoral and agency budgeting processes.

## **9.6 Recommendations for training and raising awareness**

Training will be central to successful outcomes with all the preceding recommendations. Identifying and securing the resources to develop and maintain a coherent climate resilience training programme then becomes an *a priori* requirement.

Training and capacity development in the road transport sector will benefit from the creation of a cadre of trained “climate champions” within key ministerial, government agency and private sector locations, as well as trained trainer of trainers.

Specific technical training should include:

- 1) climate and climate variability and change awareness and knowledge;
- 2) climate vulnerability assessment and risk assessment tools and methodologies;
- 3) climate impact-related data collection formats, data collection, storage, analysis and sharing; economic analysis of historical and projected patterns of climate event impact;
- 4) economic analysis of possible climate adaptation solutions for the road sector;
- 5) modelling of traffic movements in response to climate threats and disaster events.

## **9.7 Concluding remarks**

This CVA Summary Report presents the findings of a Climate Vulnerability Assessment completed by the Climate Resilient Road Infrastructure Project in 2017 and 2018. It also includes some more recent observations from UNFCCC, IPCC and other sources, inserted because of the rapidity of some climate change knowledge developments and their implications for Zambia’s road transport sector. It was concluded before the real onset of the Covid-19 pandemic and its hugely positive environmental effects.

The CVA Report stressed the need for improved communication protocols between the climate information ‘Providers’ and climate information ‘Users’ (in this case the road sector at large and others). However, it is important not to look at road sector climate impacts in isolation. Climate effects in other sectors will almost certainly impact on road infrastructure, directly or indirectly. In this context there is a considerable amount of climate resilience work being undertaken in the agriculture, health, energy and natural resources sectors. Road sector stakeholders will benefit from keeping a watching brief on

the outputs and innovations coming from the studies and initiatives, not least in the format of the National Adaptation Plan now in preparation.

The principal objective of a road transport climate vulnerability assessment is a set of clear strategies that will deliver an optimised climate resilient road sector at some point in the future. It has been argued that the objective date should be 2030, to coincide with the national Vision 2030 end date, and with one of the UNFCCC/IPCC milestones. In order to monitor progress towards road sector climate resilience objectives for 2030 the following steps are needed:

- 1) defining realistic road sector climate resilience objectives for 2030;
- 2) embedding these climate resilience objectives in sector policies, strategies, programmes, asset management systems and contracting processes;
- 3) allocating responsibilities for achieving these objectives;
- 4) providing focused financial and material support into institutional structures, processes and infrastructure that will enable successes;
- 5) supporting the cross-flow of information and ideas that will strengthen delivery of the objectives;
- 6) recognising and supporting the work of 'climate champions' who can help to facilitate climate resilience processes and also assist with overcoming the hurdles to progress that inevitably already exist and those will emerge.

Further CVAs will prove useful monitoring and planning points at key dates along the path to the 2030 objectives, not least because they require the assembly of a wide range of stakeholder inputs and the refining of CVA methodologies that are most appropriate to the Zambian road transport sector. CVAs will be most effective if embedded in a robust, but workable, climate resilience strategy for Zambia's road sector.