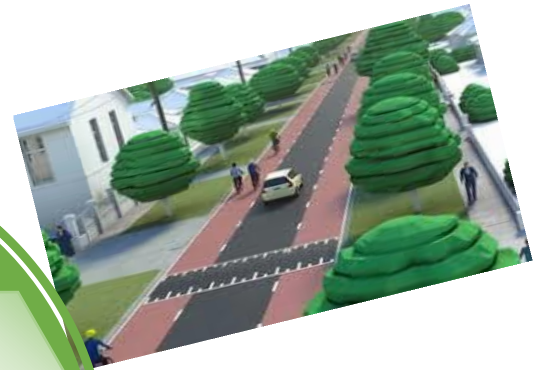
Ethiopia's Climate Resilient Transport Sector Strategy



Ministry of Transport of Ethiopia

Addis Ababa, Ethiopia

CONTENTS

LIST of TABLES iii

LIST OF FIGURES iv

ABBREVIATION AND ACRONYMS v

EXECUTIVE SUMMARY 1

CHAPTER ONE 5

1.1. Introduction 5

1.2. Vision. 8

1.3. Objectives Of The Strategy, ... 9

1.4. Achieving the Vision 17

CHAPTER TWO 18

2.1. ABOUT ETHIOPIAN CLIMATE 18

2.1.1. The Contribution of Transport to Climate Change 25

2.1.1.1. The Business as Usual Emissions Scenario 26

2.1.2. Vulnerability of Transport Infrastructure to Climate Change 27

2.1.2.1. Air Transport 29

2.1.2.2. Railway Transport 34

2.1.2.3. Road Transport 40

2.2. Projected Economic Impacts of Climate Change in Ethiopia 45

2.3. Establishing the Climate Risk Baseline for Transport Infrastructure 47

CHAPTERTHREE 50

3.1. The Path Forward to Low Carbon and Climate Resilient Transport Sector 50

3.1.1. Low carbon development path 52

3.1.1.1. Responding to the climate change 52

3.1.1.2. Reducing transport's contribution to GHGs emission (mitigation measures) 54

3.1.1.2.1. Air transport 54

3.1.1.2.2. Railway transport 57

3.1.1.2.3. Road transport 59

3.1.1.2.4. Urban Transport 67
3.1.2. Assessment of feasibility of mitigation options in Ethiopian context 69
3.1.3. Adaptation (Resilience) opportunities for reducing vulnerability to climate change risks 75
3.1.3.1. An adaptive and reactive strategy of climate resilient infrastructure 75
3.1.3.2. Recommendation for adaptation measures 80
3.2. Increased Coordination Capacity at Ministry of Transport 85
3.3. Implementation 87
3.3.1. Priority Actions for Implementation of the Strategy 87
CHAPTER FOUR 90
Conclusion 90
APPENDIXES 92
APPENDIX A – The Principles Underpinning the Vision for the Transport System 92
APPENDIX B: Problem Tree 94
APPENDIXC: Establishing Standardized Criteria for Determining Critical Assets 95
APPLICATION OF CRITERIA TO ROAD CORRIDORS 97

LIST of TABLES

Table 1: Strengthen transport planning processes – outcome and targets 11
Table 2: Improving access and mobility – outcome and targets 12
Table 3: Ensuring environmental sustainability – outcome and targets 14
Table 4: Protecting and promoting public health – outcome and targets 15
Table 5: Achieving economic efficiency – outcome and targets 16
Table 6: Matrix of degree of impact due to vulnerability to climate change 28
Table 7: Airport vulnerability matrix (rainfall, temperature and extreme events) in the time period up to 2030 33
Table 8: Rail vulnerability matrix (rainfall and temperature) for the time period up to 2030 38
Table 9: Road vulnerability matrix (rainfall and temperature) in the time period up to 2030 44
Table 10: Cumulative climate change impact on paved and unpaved roads based on increased road maintenance costs for the GCM Wet 2 and Dry 2 climate scenarios (in million USD) 47
Table 11: Climate variables relevant for the transport sector in Ethiopia 48
Table 12: Assessment of feasibility of selected mitigation options 71
Table 13: Climate resilient asset management system 78
Table 14*: Priority actions for implementation* 88

LIST OF FIGURES

Figure 1: Projected changes in mean annual temperature and precipitation in SSA in 2050 18
Figure 2: *Mean annual temperature (ºC) distribution* 20
Figure 3: *Mean annual rainfall (mm) distribution* 21
Figure 4: Historic year-to-year rainfall variability 22
Figure 5*: Known areas at risk from flooding* 24
Figure 6: Known areas at risk from precipitation driven landslides 24
Figure 7: Known areas at risk from wildfires 25
Figure 8*: Transport sector GHG emissions to 2030 under the business-as-usual scenario* 26
Figure 9: Indicative locations of airport infrastructure at risk 34
Figure 10: Indicative locations of rail infrastructure at risk 39
Figure 11 : Projected impacts of the four GCM climate scenarios on the 2010 base GDP 46
Figure 12: Transport abatement potential in the year 2030 52
Figure 13: Transport abatement potential of CRGE and selected mitigation options 74
Figure 14: *Additions to the Institutional structure to support improved coordination* 87

ABBREVIATION AND ACRONYMS

ATM	Air Traffic Management
BAU	Business-as-usual
CAA	Civil Aviation Authority
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CNG	Compressed Natural Gas
CRGE	Climate Resilient Green Economy
CRTSS	Climate Resilient Transport Sector Strategy
EAE	Ethiopian Airports Enterprise
ERA	Ethiopian Roads Authority
ERC	Ethiopian Railways Corporation
ESIA	Environmental and Social Impact Assessment
ETL	Express Toll Lane
ETS	Emission Trading Scheme
EU	European Union
FAO	Food and Agriculture Organization
FTA	Federal Transport Authority
GCM	General Circulation Models
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GoE	Government of Ethiopia
GTP	Growth and Transformation Plan
HFC	Hydro-fluorocarbon
HGV	Heavy Goods Vehicle
HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
ICD	Inland Container Depot
IFR	Instrument Flight Rules
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LRT	Light Rail Transit
MoT	Ministry of Transport
Mt CO2e	Million ton of Carbon dioxide equivalent
NGV	Natural Gas Vehicle
NO	Nitric Oxide

NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NRN	National Railway Network
PAYD	Pay as You Drive
PEV	Plug-in Electric Vehicle
PJ	Peta joules
PKT	Per person Kilometers Travelled
PM	Particulate Matter
RTN	Rapid Transit Network
RNG	Renewable Natural Gas
RTA	Regional Transport Authority
RRA	Regional Road Authority
TOD	Transit Oriented Development
USD	United States Dollar
VFR	Visual Flight Rules
VKT	Vehicle Kilometers Travelled

EXECUTIVE SUMMARY

This Climate Resilient Transport Sector Strategy sets the framework for the Government of Ethiopia to deliver an integrated, modern transport system with a strong focus on multi modal transportation links and a customer service. The vision of this Strategy is to ensure that Ethiopia's national development, poverty reduction and climate resilience goals are promoted by the transport sector. This multi-pronged focus matches the direction set by the Government of Ethiopia (GoE) in its national level strategies and provides the Ethiopian transport sector with a unified vision, mission and implementation plan:

> *An affordable, integrated, safe, responsive and sustainable transport system that enhances the environmental, economic, social and cultural wellbeing of Ethiopia's population*

Underpinning the vision are the key principles of safety, sustainability, integration and affordability, consistent with the Government's vision outlined in the Climate Resilient Green Economy Strategy and existing sectoral strategies and plans.

Within this context, five strategic objectives define the desired 2030 outcomes:

- Improved coordination of transport sector plans and results;
- Improved public transport accessibility and safety;
- Reduced exposure to the negative impacts of transport pollution on human health;
- Increased non- motorized transport mode use in urban areas;
- Reduced greenhouse gas (GHG) emissions from the transport system and network;
- Improved public transport links to and between higher density growth centers identified;
- Improved value for money from transport investment.

To achieve these outcomes the Strategy identifies a planned and coordinated set of aspirational targets and actions that also address the challenges identified in the accompanying Sector Assessment. These provide a benchmark against which to measure progress, enabling monitoring for evaluation of progress.

The identified targets are aspirational, reflecting the shift in emphasis and urgency needed to achieve the outcomes. Their achievement will be very challenging, but realistic if they are given adequate emphasis and funding, and all potential policy measures implemented. In addition, there is a need to apply increased priority to key component areas. These areas do not represent all transport activity – many of the actions delivered on a routine basis (by government, sectoral entities, regional and local authorities and private sector operators) are not represented in the strategy, but they are essential for the achievement of the targets and delivery of the vision. In pursuing these key areas, the government will achieve the CRGE transport objectives through gradual but accelerating change. In addition, many of the changes that are required, particularly in relation to vehicle technologies, have lead-in periods of 20 years or so. Small changes need to be made now to help prepare the system for major changes later on.

To support the transition from the traditional single mode transport planning to multi-mode and accessibility planning, improved coordination between plans and programs and the development of a clear hierarchy of plans and strategies are required, combined with a better understanding of the trade-off elements that improved integration will bring. To date, transport modes have been developed individually without a cohesive, overarching approach and their goals and investments are not linked to each other leading to confusion, duplication and lack of synchronicity.

To address this, the Strategy is envisioned as an overarching framework to guide the development of a series of subsequent and more detailed transport plans, policy decisions, reforms and funding decisions. This Strategy is not a detailed step-by-step plan for all transport initiatives. Rather, each agency, in line with their mandated responsibilities, will develop the appropriate detailed plans and strategies. These detailed plans will directly address local and regional level issues, and will contain a greater amount of operational detail than is appropriate in a national Strategy or a national master plan.

Within this overarching framework, the focus is on the three aspects of the transport system that drive its use and shape its long-term sustainability:

- Freight transport plan;
- Urban mobility and transport plans; and
- Integrated modal delivery plans.

To ensure concurrency between the different planning levels of the Ethiopian state, each of these aspects will be addressed at the national, regional and local (urban) levels, as appropriate, through:

- National plans;
- Regional transport plans; and

- Urban transport plans.

Where these documents already exist, they will need to be updated to ensure that the aims and objectives of the Strategy are included and addressed. The majority of envisioned documents, however, are new, presenting sectoral partners with opportunities to advance and refine their approach to implementation. In this way, regional and local (urban) transport plans are linked to the national Strategy to ensure that expected growth and changes in each region are considered and integrated into the national planning decisions. This framework approach ensures that not only is transport planning closely aligned with national policies and future growth, but also that the appropriate transport services are provided and that best use is made of infrastructure and investments through modal synergies and planning efficiencies.

The Strategy is a "living document," and should be adapted as Ethiopia evolves over the next fifteen years. The outlined approach also complements the CRGEs overall direction, which for the transport sector is an explicitly tactical one. The CRGE Strategy focuses on individual transport modes and already includes some of the major mitigation options that would typically be recommended for inclusion in a transport sector GHG abatement program. For the majority of identified abatement levers in the CRGE Strategy, implementation has already begun. During the accompanying Sector Assessment, additional opportunities for gains in emission reductions were identified within and in support of the CRGEs defined implementation pathway. For the most part, these reflect opportunities for additional tactical gains within the boundaries of traditional single transport mode approaches and can be managed as part of the technical and operational functions of each sub-sector. Among these emission reduction opportunities are:

- Introduction of regenerative braking to NRN and LRT operations by ERC;
- Establishment of flight management and operation, as well as, surface, terminal and technical support facilities emission reductions by CAA and EAE;
- Reduction of operational emissions by updating road and rail construction processes by ERA and ERC; and
- Introduction of high albedo pavement blends to road construction and resurfacing schedules by ERA.

To help bridge the gap between majority of adaptation and mitigation opportunities identified in the Sector Assessment, which are tactical in nature, and the strategic need for a cohesive, long-term approach to transition the sector towards a low-carbon future, this Strategy also focuses on managing demand for travel and shifting to lower emission transport modes. This not only supports the sector becoming more responsive to socio-economic development needs but also provides a high-level response to many of the challenges currently facing the sector by supporting greater concurrency and integration as a response to the identified sector challenges.

The framework approach is also an adaptation strategy, by and in itself, as it is directed towards reorienting the sector towards sustainable transport and increased integration with land use development. This transition will occur through increased planning concurrency leading to improved coordination between plans, programs and a focus on multi-modal transport and accessibility planning. In this way, the Strategy positions Ethiopia to benefit from multi-modal transport synergies and cost-efficiencies while increasing the potential to realize GHG emission reduction gains.

CHAPTER ONE

1.1. Introduction

Ethiopia is in a period of transition. The last 20 years have seen the country enter the modern era. The next 15 years will see it hugely transformed in terms of socio-economic progress and adoption of carbon neutral/low carbon approaches and technologies. In particular, investments in basic infrastructure and services will ensure that Ethiopia emerges as a middle-income economy.

Ethiopia in 2030 will be very different from the Ethiopia of today, and the transport system needs to respond to the changing needs and demands. This Climate change Resilient Transport Sector Strategy (Strategy) is part of the government's broad vision for a sustainable, prosperous Ethiopia, secure in its identity and proud of its achievements.

However, Ethiopia has historically suffered from climatic variability. Repeated rain failures, famines and chronic food crisis resulting from frequent droughts, environmental degradation and decline in food production have rocked the country many times and remain a major challenge. Ethiopian economic output growth closely linked to fluctuations in the precipitation levels, as its agriculture is highly rain-fed, with only 2% of total arable land covered by irrigated and permanent crops. This strong association between rainfall and the economy is largely due to the nature of the country's most dominant sector, agriculture, and weak capacity of the rural population to adapt to climate variations.

The current four-decade trend for the country's most significant climate indicators and the analysis used in the climate projections for development of the CRGE is based on a set of climate models, downscaled to national level and based on the Intergovernmental Panel on Climate Change (IPCC) A2 emissions scenario. These models provide the illustrative 'envelope' of feasible outcomes and are, therefore, useful for identifying the broad climate trends and risk areas.

Rainfall: Precipitation has shown a general decreasing trend since the 1990s. The decrease in precipitation has multiple effects on agricultural production and water availability for irrigation and other farming uses, especially in the north, northeastern, and eastern lowlands of the country.

It is very difficult to detect long-term rainfall trends in Ethiopia. The climate models indicate that when compared to the annual precipitation in the base period (1961 – 1990), there is a change of between

0.6 – 4.9% for 2030 and between 1.1 – 18.2% for 2050. The percentage change in seasonal rainfall is expected to be up to about 12% over most parts of the country:

- In the West, there will be broadly similar seasonal (i.e. month-to-month) rainfall patterns, with any changes in annual rainfall being spread across the year.
- In the Central and Eastern region, there may be shifts in monthly rainfall patterns. The wettest scenarios indicate an increase in rainfall outside of the main *kiremt* rains. The driest scenarios, however, indicate that there could be a shorter *kiremt* period with less rain overall and more significantly that the smaller *belg* rains may be reduced or even lost altogether.
- For the South and Southeastern region, the models show a diverse range of outcomes. The wettest scenarios indicate that the main rains could come earlier and that *secondary* rains could be longer. The driest scenarios indicate a drastic fall in the main rainy season that may have major consequences for food security in Somali, Amhara and SNNPR.

Year-to-year variability is likely to remain high and all the models indicate a broader spread of variability. This means that Ethiopia is likely to see an increase in extremes of rainfall and a broader range of rainfall.

The models disagree on the degree and direction of overall rainfall levels *of long-term mean rainfall* with outputs that vary from a reduction in rainfall of 25% to an increase of 30%. Different parts of the country will experience different impacts:

- In the West, the models range from a decrease of 37% to an increase of 13% in mean rainfall. The wettest scenarios show a slight decrease in variability, but the driest scenario indicates an increase in variability;
- The rest of country could see significant change in seasonal rainfall pattern during key times (belg rain for the Central and Eastern region; gu rains for the South and South-Eastern);
- Across the country, year-to-year variability is high (as the differences between a dry' and a 'wet' year can range from 28% to 62%) and this variability is likely to increase – indicating more uncertain rainfall and more frequent extremes;
- Long-term changes in mean annual rainfall are less significant than the year-to-year rainfall variability. Although the models indicate that parts of the country will be wetter, this is outweighed by the high annual variability and the potential shifts in seasonal rainfall.

Temperature: The average annual temperature in Ethiopia has increased by 0.37ºC every ten years at a rate slightly lower than the average rise in global temperature. The majority of the temperature increase was observed during the second half of the 1990s. Temperature increases are more pronounced in the dry and hot spots regions, located in the northern, northeastern, and eastern parts of the country. The most affected regions are the lowland ones, as these areas are largely dry and exposed to flooding during extreme precipitation in the highlands. There is a relatively high degree of certainty about temperature changes due to climate change.

The climate models all agree that there will be an overall increase in temperatures across the country and the region, with a decrease in the variability of temperatures. The models indicate that the mean annual temperature will increase, when compared to the 1961 – 1990 base period, in the range of 0.9 – 1.1ºC by 2030, in the range of 1.7 – 2.1ºC by 2050 and in the range of 2.7 – 3.4ºC by 2080. The CRGE uses the outer range of parameters for the period up to 2030, projecting an increase in temperatures of 0.5 – 1.5ºC by the 2020 and of 1.5 – 3ºC by the 2050s. This increase is equivalent to an increase of 0.1 – 0.4ºC per decade. Overall, the data points to warmer and more consistent temperatures across the country.

Temperature increases will have serious socio-economic consequences, especially for water resources and agricultural production, because of the increase in evapotranspiration rates and reduced soil moisture content and atmospheric humidity. These changes will be most impactful in high rainfall, highland areas that account for over 80% of the total population and for 95% of the cropped land.

Extreme climatic events: Extreme climatic and weather conditions have become increasingly common and costly. The geographic coverage, intensity and frequency of drought have increased, while desertification in the Ethiopian lowlands is expanding. Flooding due to periodic and unprecedented precipitation in the highland regions is also increasing.

Ethiopia has already seen some extreme weather events since 2000 that may be linked to climate change. These include: (a) Major floods occurred in different parts of the country in 1988, 1993, 1994, 1995, 1996, and 2006 and caused tremendous property damage; and (b) Droughts and floods are very common phenomena in Ethiopia with significant events occurring every three to five years. According to World Bank, the country has experienced at least five major national droughts since the 1980s, along with dozens of local droughts. Over the years, the frequency of droughts and floods has increased in many areas resulting in loss of lives and livelihoods, in particular, food shortages, and climate-sensitive human and crop diseases in the northern highland and southern lowland regions. These extreme weather events cause significant economic loss in a number of sectors, including transport.

1.2. Vision.

In developing the Strategy, a great deal of consideration was dedicated to improving how transport services and infrastructure can help Ethiopia reach its economic, social and environmental goals over the next 15 years. This two-pronged focus also matches the direction set by the government in the CRGE and the GTP II and I. The resulting vision statement describes the desired state of the Ethiopian transport system by 2030:

> ***An affordable, integrated, safe, responsive and sustainable transport system that enhances the environmental, economic, social and cultural wellbeing of Ethiopia's population***

Underpinning the vision are the key principles of safety, sustainability, integration and affordability, consistent with the Government's vision outlined in the CRGE and existing sectoral strategies and plans:

- *Integrated* – There are three aspects to integration: integration between all transport modes and policy so that travel from one end of a journey to the other is straightforward and seamless, integration of land use and transport planning and inter-agency integration.
- *Responsive* – The transport system needs to be responsive to users by recognizing that people wish to travel and move freight at different times and by different modes.
- *Safe* – The transport system needs to be based on design, operating and maintenance standards that protect people and property
- *Affordable*– The transport system needs to be affordable for individuals, households and businesses while infrastructure investments are cost-effective and represent value for money for all levels of government; and
- *Sustainable* – The transport system needs to proactively, boldly and creatively contribute to achieving Ethiopia's economic, social, environmental and cultural goals, securing its resilience through low carbon development approaches.

Additional details on the principles for the transport system are provided in Appendix A.

1.3. Objectives Of The Strategy,

Articulation of the vision for the Ethiopian transport system led to the identification of a series of strategic objectives. These objectives describe what the country will focus on to achieve the vision in the next 15 years.

Many of the objectives relate to each other. For example, improving access and mobility assists economic development as it improves the ability of employees to move around. Improving environmental sustainability by reducing air pollution also relates to protecting and promoting public health. However, in order to measure progress clearly, and reduce overlap between the objectives, outcomes and indicators, each objective has been framed to focus on a specific aspect of the vision. No single objective can be seen in isolation rather, they should be considered a part of an integrated strategic view of Ethiopia's transport system. However, the need for transport to be more responsive to issues, such as climate change, means there will be a focus on achieving better environmental outcomes in the short- to medium-term. More widely, it is expected that federal and regional government decision-making on the development of the transport system will collectively contribute to all of the objectives.

The objectives are further defined by a set of specific outcomes desired by 2030. The outcomes have been described as 'main outcomes' and 'related outcomes' to clearly signal priorities for the Strategy in the coming years. The main outcomes of the Strategy are:

- Reduced exposure to the negative impacts of transport pollution on human health, safety and environment;
- Reduced greenhouse gas (GHG) emissions from the transport network;

In addition to indicators related to the outcomes targets, there is also a set of contextual measures gathered and reported as part of the monitoring program. Contextual measures have no targets associated with them, primarily because it is not the intent of the Strategy to change these. However, they provide a view of the environment that the transport system operates within. They help to identify the demands on, and investment in, the transport system and can be used to identify trends that might be relevant to the strategy.

OBJECTIVE 1: STRENGTHEN TRANSPORT PLANNING PROCESSES

This objective looks to strengthen transport-planning processes at the institutional level by:

- Improving the governance and administration of the transport system and integration of planning approaches to urban growth centers and corridors in order to reduce the negative impacts of the transport network on the environment, and
- Promoting sustainable approaches to transport in order to reduce GHG emissions and reliance on non-renewable resources

> *A sustainable transport system is integrated with the land use pattern it serves and is served by. While Addis Ababa and other urban areas continue to expand they are also becoming denser. An integrated planning approach aims to manage the majority of future growth into well-designed urban growth centers and corridors. The successful development of these centers and corridors will require continually improving the governance and administration of the transport system as well as evidence-based transport infrastructure that is well designed and supports urban development, reduces travel demand, and supports public transport and active modes.*

This objective involves ensuring that the transport system supports an integrated approach to land use and transportation planning improving public transport, roads and walking and cycling links to and between high-density growth centers, as well as supporting the development of corridors. The successful development of integrated centers and corridors requires a continually improving transport governance and administration system, as well as, systemic data collection to support evidence-based decision-making. Many aspects of integrating land use and transport are covered under other objectives.

The table below presents the outcomes defined to achieve this objective and the targets used to measure progress towards the outcomes and the objective.

Table 1: Strengthen transport planning processes – outcome and targets

Outcome	Performance Target
Main outcome: Improved coordination of transport sector plans and results	Greater degree of input into and oversight of plans created by transport sub-sectors and MoT
	Improved coordination and inputs by different sub-sector into development of other sub-sectoral strategies and plans
	Establishment of clear hierarchy of strategic and development plans for all entities within the sector and a formal mechanism to reconcile the various plans
	Establishment of sectoral asset management database that includes evidence based climate risk aspects for all level of infrastructure assets and all sub-sectors
	Better coordination of policy, planning, investment, enforcement, maintenance and regulation of the transport sector
	Contextual indicator: Clarification and streamlining of mandates and responsibilities for all the transport sector entities
	Contextual indicator: Establishment of a well-capacitated coordination unit at the MoT with a mandate to oversee, and if needed, direct strategic and overall planning for transport (and sub-sectors) with prioritization among different modes; information gathering and analytic responsibility to support key policy decisions.
Main outcome: Improved public transport links to and between identified higher density growth centers	Increase in the number of identified growth centers and economic corridors with RTN services
	Increase in the percentage of people who live within 800m of a RTN stop.
	Increase in the relative land values within 800m of RTN stations
	Contextual indicators: • Number of employees and businesses within defined growth and activity centers; • Number of residents and number of dwellings within defined growth and activity centers; • The proportion of growth in developments occurring outside Addis Ababa's metropolitan urban limit; and • Number of building permits issued in different land categories (general rural, rural household, metropolitan urban limit, infill, growth centers, corridors, etc.)

OBJECTIVE 2: IMPROVING ACCESS, MOBILITY AND QUALITY OF SERVICE

This objective focuses on improving the ability of people to get around easily, affordably and reliably, with multiple travel options and by improving the quality of their travel experiences.

> *Transport networks exist so people can get around easily and travel safely to work, places of education, shops, recreation and other destinations to meet their social, economic and cultural needs. Provision needs to be made for a range of travel choices, with some active modes, needing more active establishment. To enable everyone to actively participate in society, special attention needs to be given to those whose travel choices are limited by disability, socio-economic status or provision of choices. Personal security and safety concerns are significant barriers to increasing active and public transport use that need to be addressed as part of improving access and mobility.*

The table below presents the outcomes to achieve this objective and the targets used to measure progress towards achieving the outcomes and the objective. The main outcome sought is improved public transport accessibility for all. Outcomes and indicators focused on increasing non-motorized transport modes (walking and cycling) are covered under other objectives.

TABLE 2: IMPROVING ACCESS AND MOBILITY – OUTCOME AND TARGETS

Outcome	Performance Target
Main outcome: Improved public transport accessibility for all	Increase in weekday public transport mode share for all trips (measured in trip legs) to 40%
	Increase in the proportion of public transport vehicles with low doors and wheelchair provision to 100%
	All services running on the rapid transit network (RTN) meet minimum service level guidelines (to be developed)
	Overall intercity journey times are reduced by 20%
	Contextual indicator: The level of public transport subsidy per passenger
Improved community connectedness	Increase in non-motorized transport mode share in urban areas (measured in terms of trip legs) to 35%
	Improvement in perception of non-motorized transport (walking and cycling) accessibility (measured in terms of the proportion of people who feel that a person could get around a city extremely or quite well by walking or cycling)

Outcome	Performance Target
	Improvement in the perceptions of access to work and study (measured in terms of the proportion of people who rated each mode suitable for 'most' or 'all' of their trips to study or work)
	Improvement in regional public transport access to key employment areas and essential services (measured in terms of generalized costs).[1]
Improved quality of public transport services	Improvement in journey times on selected RTN routes versus equivalent journeys by private vehicle or 'blue and white' minibuses. (No baseline data available)
	The roll-out of RTN is delivered according to plan or faster
	Contextual indicator: Travel information and ease of use of public transport system are improved

OBJECTIVE 3: ENSURING ENVIRONMENTAL SUSTAINABILITY

This objective looks to reduce the negative impacts of the transport network on the environment, promote sustainable approaches to transport in order to reduce GHG emissions and reduce reliance on non-renewable resources.

The transport system and motor vehicles in particular are currently a major source of adverse environmental effects in Ethiopia. The transport system can have adverse effects on ecosystems (including communities), water and air quality natural reserves and wildlife, climate change, cultural and natural heritage sites, noise and amenities. The pressures imposed by the transport system on the natural and physical environment are likely to increase as Ethiopia's economy grows. A well-designed transport system reduces reliance on non-renewable resources, improves energy efficiency and fits into the natural and physical environment in ways that avoid, remedy or mitigate adverse effects on the environment.

Ethiopia's transport network must take into account the effects it will have on the environment. This reflects greater global awareness of the environmental impacts of transport and the need for sustainable development.

[1] Travel cost made up of the financial cost and the time cost. Often calculated using transport models.

Some aspects of transport related pollution (particularly air and noise) have direct impacts on human health, and as a result, the outcomes and targets for air and noise pollution are covered under other objectives.

The next **table 3** presents the outcomes defined to achieve this objective and the targets used to measure progress towards the outcomes and the objective. The main outcome sought is reduced GHG emissions from the transport network.

TABLE 3: ENSURING ENVIRONMENTAL SUSTAINABILITY – OUTCOME AND TARGETS

Outcome	Performance Target
Main outcome: Reduced greenhouse gas emissions from the transport network	Reduce per capita GHG (gross CO_2 equivalent) emissions from domestic transport, relative to 2010 levels, by 64% by 2030
Increased use of sustainable modes of transport for moving people	Public transport mode share during the morning peak period increases
	Increase in walking and cycling mode share across urban centers
	Overall reduction in the number of trips undertaken with private and motorized vehicles
Improved protection of sites with historic, environmental and cultural value	No accurate measures are available, however, transport projects are expected to undertake environmental impact assessments as standard project planning and design
Improved storm water quality	Measures to address storm water quality and storm water treatment are highlighted during construction and maintenance projects to reduce their potential to impact on transport infrastructure
Increased use of sustainable modes of transport for freight movement	Increase in rail mode share for freight movement.
	Contextual indicator: Uptake of government incentives for adopting fuel efficient technology options for freight vehicles
Increased use of recycled and renewable material, and reduced waste from transport projects	• Increase in volume of recycled material used in transport projects • Reduction in the volume of liquid and solid wastes from transport projects going to landfill

OBJECTIVE 4: PROMOTING PUBLIC HEALTH AND REDUCING SOCIAL DISADVANTAGE

This objective looks to improve community health by promoting non-motorized modes of transport, to protect public health by reducing exposure to health-impacting pollutants from the transport system and to reduce social disadvantage by promoting equality of access to goods, services, and employment and education opportunities.

> *Transport plays a vital role in building healthy and equitable communities. Reducing the levels of congestion, the amount of travel by motor vehicles, and improving fuel quality and engine technology can improve public health by reducing harmful pollutants and GHG emissions. Encouraging* non-motorized transport *choices can also improve individuals' health – both mental and physical. Improving access to goods, services, and employment and education opportunities for people across all parts of the country and to enable everyone to participate actively in society, special attention needs to be given to those whose travel choices are limited by disability, socio-economic status or provision of choices.*

The table below presents the outcomes defined to achieve this objective and the targets used to measure progress towards the outcomes and objective. The main outcomes sought are reduced negative impacts of transport pollution on human health and increased walking and cycling.

TABLE 4: PROTECTING AND PROMOTING PUBLIC HEALTH – OUTCOME AND TARGETS

Outcome	**Performance Target**
Main outcome: Reduced exposure to the negative impacts of transport pollution on human health	A reduction in the average annual concentrations of transport-related pollutants (PM2.5, PM10, NO and NO_2/NO_x) at selected roadside locations
	The number of times that health standards for the following air quality measures are exceeded at selected roadside locations is no more than: 9 occurrences p.a. for NO_2; 1 for PM10 and CO and 0 for PM2.5
	Improvement in reducing traffic noise-related exposure
Main outcome: Increased walking and cycling	Increase in walking and cycling mode share in urban areas (measured in terms of trip legs) to 35%
	Increase in the average distance travelled by walking per person over five years of age to 1.3 km per day

Outcome	Performance Target
	Increase in the number of cyclist movements at defined survey points
Improved street design (for people and environment)	Improved perceptions of walkability of urban neighborhoods and business districts
	Increase in the availability of variety of trip leg options for business and educational purposes

OBJECTIVE 5: ACHIEVING ECONOMIC EFFICIENCY

This outcome looks to ensure that better fuel efficiency and investments in the transport system deliver value for money, for both new investment and for maintaining and utilizing the existing transport network infrastructure.

Economic efficiency means that Ethiopia's limited financial resources invested in the transport system minimizes costs and externalities and maximizes the tangible and intangible benefits it generates. Transport initiatives that deliver better fuel efficiencies will also result in significant benefits such as reduced cost, improved security of energy supply and reduced GHG emissions.

The table below presents the outcomes defined to achieve this objective and the targets used to measure progress towards achieving the outcomes. The main outcome sought is improved value for money from transport investments.

TABLE 5: ACHIEVING ECONOMIC EFFICIENCY – OUTCOME AND TARGETS

Outcome	Performance Target
Main outcome: Improved value for money from transport investments	No projects deliver less than the projected benefit/cost ratio
	Contextual indicator: Maintenance costs of road by vehicle kilometers travelled (VKT)
Improved use of the existing transport network	Increase (triple) the average number of public transport boarding per person p.a.

Outcome	Performance Target
	Contextual indicators: • Volumes of vehicles at locations on network over day • Public transport passenger km/seat km. • Increase in the average occupancy rate of vehicles
	The design life of infrastructure accounts for climate variations and the maintenance schedule ensures that the service levels remain high throughout the life of the asset
Increased energy efficiency from the transport network	Reduction in energy use in petajoules (PJ) per person kilometers travelled (PKT) by domestic transport
	Contextual indicator: Proportion of energy use in the transport sector by source of energy (petrol, diesel, liquefied petroleum gas (LPG), compressed natural gas (CNG), and electricity in the transport sector
	Reduction in percentage of GDP spent on transport fuel
	Reduction in percentage of carbon emissions generated by the transport sector against 2010 levels
	Increase in the percentage of trip legs conducted on energy efficient public transport options

1.4. Achieving the Vision

For the foreseeable future, there is a need to apply increased priority to key component areas, particularly to address the key challenges facing the sector and help achieve the targets. These areas do not represent all transport activity – many of the actions delivered on a routine basis (by government, sectoral entities, regional and local authorities and private sector operators) are not represented here, but they are essential for the achievement of the targets and delivery of the vision.

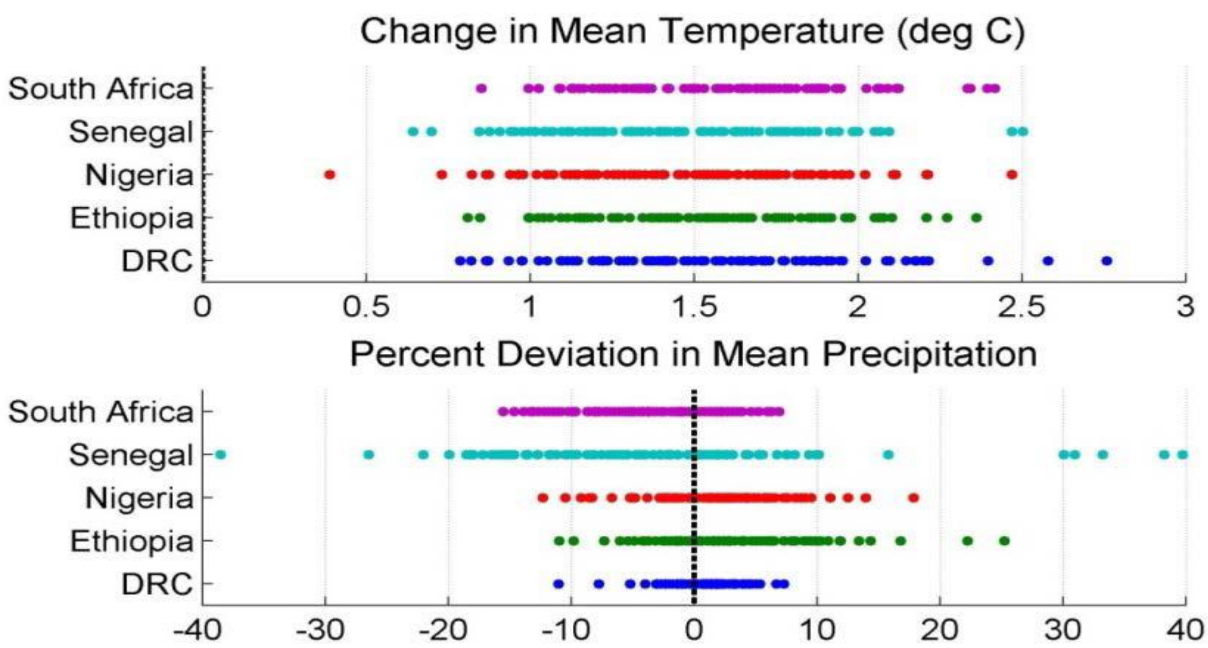
In pursuing these key areas, the government will achieve the CRGE transport objectives through gradual but accelerating change. In addition, many of the changes that are required, particularly in relation to vehicle technologies, have lead-in periods of 20 years or so. Small changes need to be made now to help prepare the system for major changes later on.

CHAPTER TWO

2.1. ABOUT ETHIOPIAN CLIMATE

Climate Change Projections Climate change is projected to bring about substantial changes across SSA in temperature and precipitation (see Figure O.2 for the projected change in five sample countries). The countries were selected based on their present-day climates, which represent the range of climates found across SSA. As shown in the figure, temperature is projected to rise uniformly across the climate models and countries. The projected change in mean precipitation is more uncertain, and varies substantially across countries.

FIGURE 1: PROJECTED CHANGES IN MEAN ANNUAL TEMPERATURE AND PRECIPITATION IN SSA IN 2050



Note: In each country, each dot denotes an annual representation of climate. In the precipitation panel, the vertical zero line corresponds to current (recent historical) mean annual precipitation. Dots to the right of the historical value refer to projections of wetter climate; dots to the left indicate projections of drier climate.

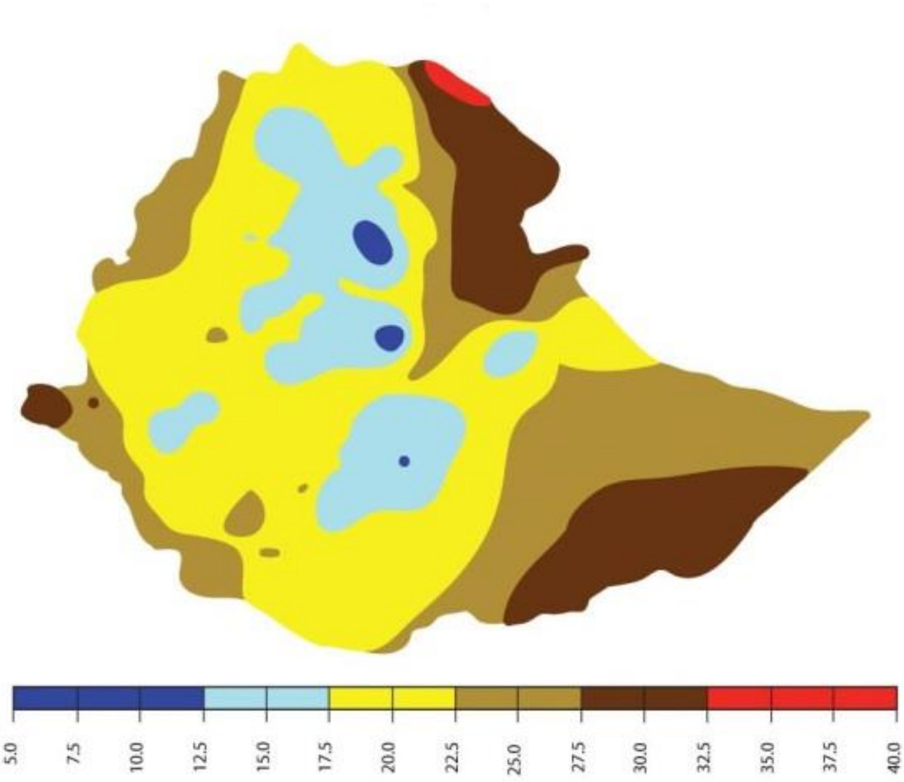
Ethiopia has one of the most complex and varied climates in the world due to its geographical location, within the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) and its associated atmospheric circulations, and its diverse topography. The climate is typically tropical in the south- and north-eastern lowland regions, and cooler in the large central highland regions of the country.

Mean annual temperatures are around 15 – 20ºC in the high altitude regions, and 25 – 30ºC in the lowlands. *Month-to-month* temperature variations across Ethiopia are relatively limited – around 4ºC between the hottest and coolest points in the year. Y*ear-to-year* temperature variations fluctuate around the mean temperature, at most around ±0.8ºC from the long-term trend. The *10-year trend* for the last 30 years, however, shows that there has been a steady and significant increase in the long-term mean temperature of around 0.8ºC. Between 1951 and 2006 annual minimum temperature in Ethiopia has been increased by about 0.37°C every decade. The UNDP Climate Change profile for Ethiopia also shows that the mean annual temperature has increased by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade (McSweeney, 2010). The temperature increase has been most rapid from July to September (0.32°C per decade). Reportedly, the average number of hot days per year has increased by 73 (an additional 20% of days) and the number of hot nights has increased by 137 (an additional 37.5% of nights) between 1960 and 2006. The rate of increase was highest in June, July and August. Over the same period, the average number of cold days and nights has decreased by 21 (5.8% of days) and 41 (11.2% of nights), respectively. These reductions have mainly occurred in the months of September to November (McSweeney, 2010).

Furthermore, a study on climate change projections specific to Ethiopia, undertaken by the University of Oxford, depicts that mean annual temperature in the country would increase by 1.1 to 3.1°C by the 2060s, and 1.5 to 5.1°C by the 2090s and could reduce GDP by 3-10% by 2025 (McSweeney, 2010).

The majority of the variance in the minimum and maximum temperatures appears to be located in the central region.

FIGURE 2: *MEAN ANNUAL TEMPERATURE (ºC) DISTRIBUTION*



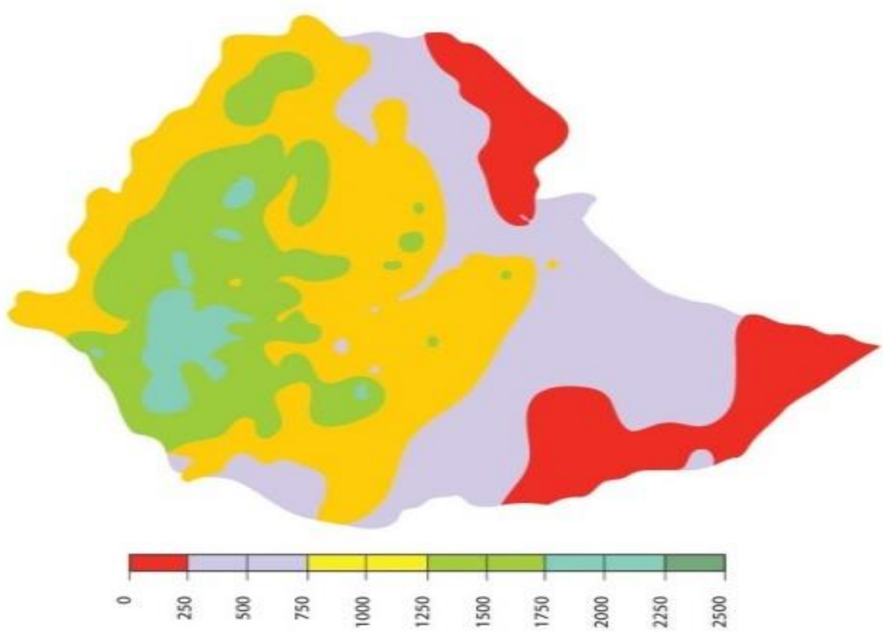
SOURCE: NATIONAL HUMAN DEVELOPMENT REPORT, 2009

According to the rainfall data analysis of Ethiopia, the mean annual rainfall ranges from 2000 mm in the highland areas in the southwest part and less than 250 mm in the eastern and southeastern lowland parts of the country. In general, annual precipitation ranges from 800 to 2200 mm in the highlands (>1500 m above sea level.) and varies from less than 200 to 800 mm in the lowlands (<1500 m above sea level). Rainfall also decreases northwards and eastwards from the high rainfall areas in the southwest. The distribution of rainfall is also uneven for both rain seasons. The summer rainfall covers most of the highlands of the country and lasts from the months of June to September for a year. The results of the long year rainfall analysis show that summer rainfall amount has been declining. On the other hand, the southern parts of the country are receiving maximum rain during the months of March to May and a similar trend has recorded (Solomon, *et al.* 2015).

Rainfall variability is one of the most significant climate variables for Ethiopia. Analysis of the inter-annual variation of rainfall for 1951 – 2010 shows fluctuations in the total annual rainfall from one year to the next. The *year-to-year* rainfall variability from the average rainfall is particularly stark in the South and Southeastern regions, with annual rainfall varying between +36% and -25% of the mean. The *mean annual rainfall* shows a slight decreasing trend, indicative of a decrease in the total annual rainfall over the years. At the same time, the seasonal rainfall performance is highly dependable (i.e., less variable) in the high rainfall areas, and highly variable (i.e., less reliable) in the low rainfall areas. The *long-term rainfall trend*, however, is inconclusive and there is no clear change in the long-term mean rainfall. Overall, Ethiopia has strongly seasonal and regionally distinct rainfall patterns, with high overall rainfall variability from year-to-year.

The study also found that projections from different climate models were broadly consistent indicating increases in average rainfall in Ethiopia, primarily through increases in rainfall during the shorter of southern Ethiopia's two rainy seasons (in October, November and December), with more mixed projections for the rest of the country and that more rain would fall in 'heavy' events (Alex, 2012).

FIGURE 3: *MEAN ANNUAL RAINFALL (MM) DISTRIBUTION*

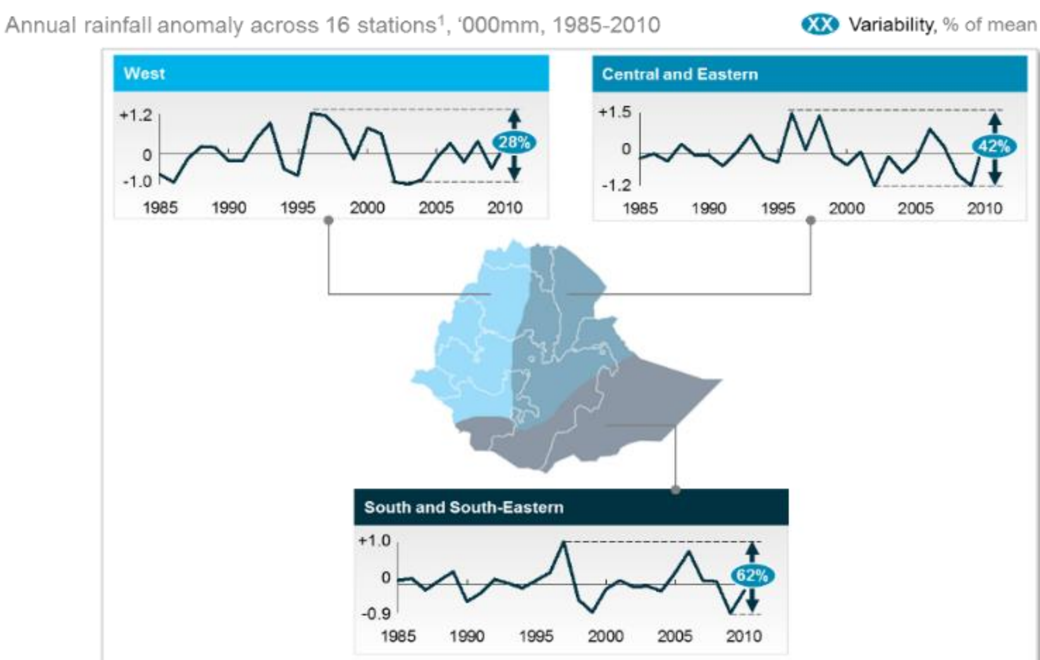


Source: National Human Development Report, 2000

The movements of the ITCZ are sensitive to variations in Indian Ocean sea-surface temperatures and vary from year to year, resulting in considerably inter-annual variability in the onset and duration of the rainfall seasons, causing frequent droughts. Seasonal rainfall in Ethiopia is generally correlated with altitude and is driven by the migration of the ITCZ. In general, average annual rainfall in areas above 1,500 meters exceeds 900 mm. In the lowlands (below 1,500 meters) rainfall is erratic and averages below 600 mm. The position of the ITCZ changes over the course of the year, oscillating across the equator. As a result, *month-to-month* rainfall patterns differ across the country depending on geography with three broad hydrological regimes:

- **West**: One long rainy season, *kiremt* (June-Sept), when the ITCZ is at its northern-most position;
- **Central and Eastern**: *kiremt* (June-Sept) as the main rainy season, preceded by smaller *belg* rains (March-May). There is a short hot, dry period known as *bega* (October-January);
- **South and Southeastern**: Two distinct wet seasons that occurs at the ITCZ passes through the main rainy season in February–May and the secondary rainy season in October – November. The rainy seasons are separated by two pronounced dry seasons.

FIGURE 4: HISTORIC YEAR-TO-YEAR RAINFALL VARIABILITY



1 Averages extrapolated for 7% of missing data-points, *West* includes Debre Markos, Gondar, Gore, Jimma, Nekemte. *Central and Eastern* includes Addis Ababa, Awassa, Combolcha, Debre Zeit, Dire Dawa, Mekele, Metehara, Robe. *South and South-Eastern* includes Arba Minch, Gode, Neghele

Source: NMA

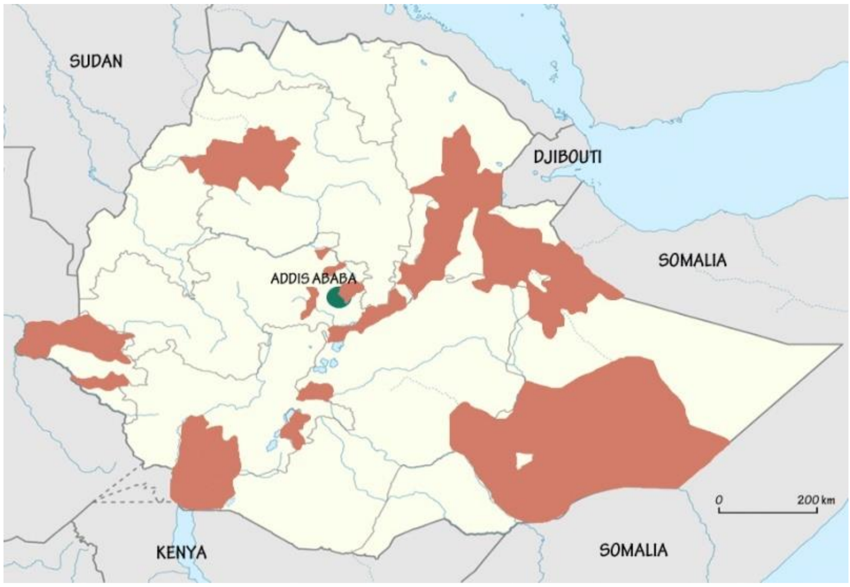
Ethiopia has historically suffered this climatic variability. Repeated rain failures, famines and chronic food crisis resulting from frequent droughts, environmental degradation and decline in food production have rocked the country many times and remain a major challenge. Ethiopian economic output growth is closely linked to fluctuations in the precipitation levels, as its agriculture is highly rain-fed, with only 2% of total arable land covered by irrigated, permanent crops. This strong association between rainfall and the economy is largely due to the nature of the country's most dominant sector, agriculture, and weak capacity of the rural population to adapt to climate variations.
The current four-decade trend for the country's most significant climate indicators is:

- **Temperature:** The average annual temperature in Ethiopia has increased by 0.37ºC every ten years at a rate slightly lower than the average rise in global temperature. The majority of the temperature increase was observed during the second half of the 1990s. Temperature increases are more pronounced in the dry and hot spots regions, located in the northern, northeastern, and eastern parts of the country.
  The most affected regions are the lowland ones, as these areas are largely dry and exposed to flooding during extreme precipitation in the highlands.
- **Rainfall:** Precipitation has shown a general decreasing trend since the 1990s. The decrease in precipitation has multiple effects on agricultural production and water availability for irrigation and other farming uses, especially in the north, northeastern, and eastern lowlands of the country.

- **Extreme climatic events:** Extreme climatic and weather conditions have become increasingly common and costly. The geographic coverage, intensity and frequency of drought have increased, while desertification in the Ethiopian lowlands is expanding. Flooding due to periodic and unprecedented precipitation in the highland regions is also increasing.

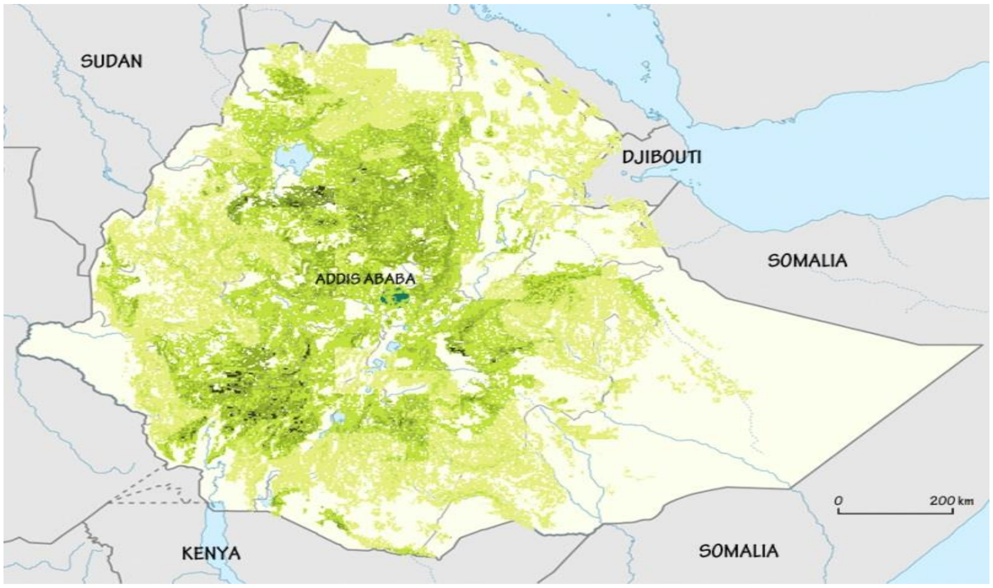
The following is the known extant of the most likely climate based hazards in Ethiopia.

FIGURE 5*: KNOWN AREAS AT RISK FROM FLOODING*



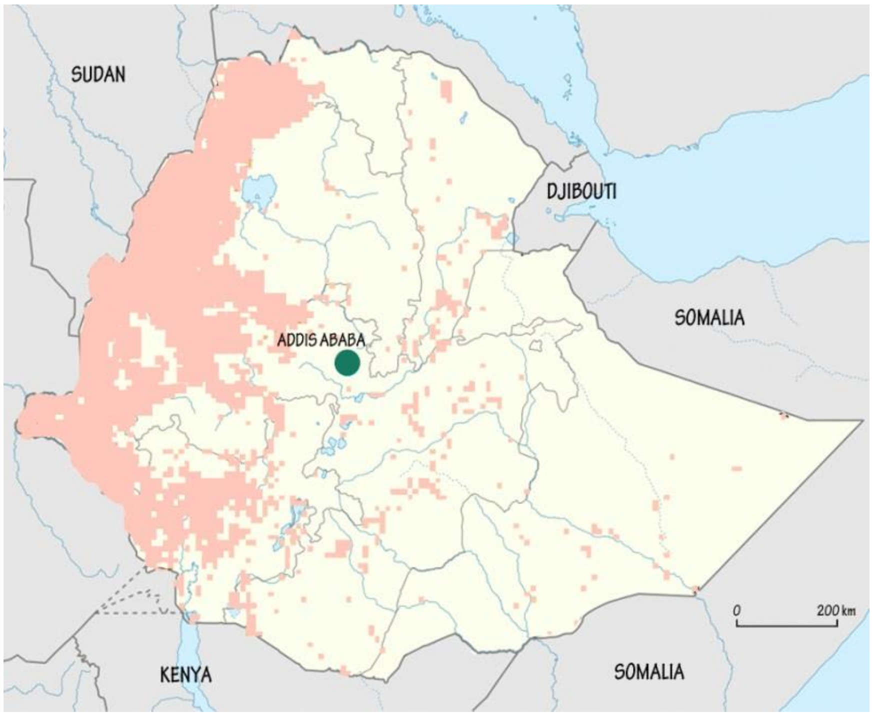
Legend: ● Area at risk from flooding
Source: Based on the 2006 flood maps generated by DPPA and NMA

FIGURE 6: KNOWN AREAS AT RISK FROM PRECIPITATION DRIVEN LANDSLIDES



Legend: ● Area at high risk from precipitation driven landslides; ● Area at low risk from precipitation driven landslides
Source: Based on the information contained in UNEPs Global Risk Data Platform

FIGURE 7: KNOWN AREAS AT RISK FROM WILDFIRES



Legend: ● Area at risk from wildfires
Source: Based on the information contained in UNEPs Global Risk Data Platform

2.1.1.The Contribution of Transport to Climate Change

GHG emissions from the transport sector are among the fastest in Ethiopia as fast-paced economic growth, growing affluence and urbanization are translated into more widespread vehicle ownership, increasing trip numbers and lengths. Demand for transport is increasing over time for each of the transport modes – road, rail, shipping and air with corresponding increases in the volume of transport emissions.

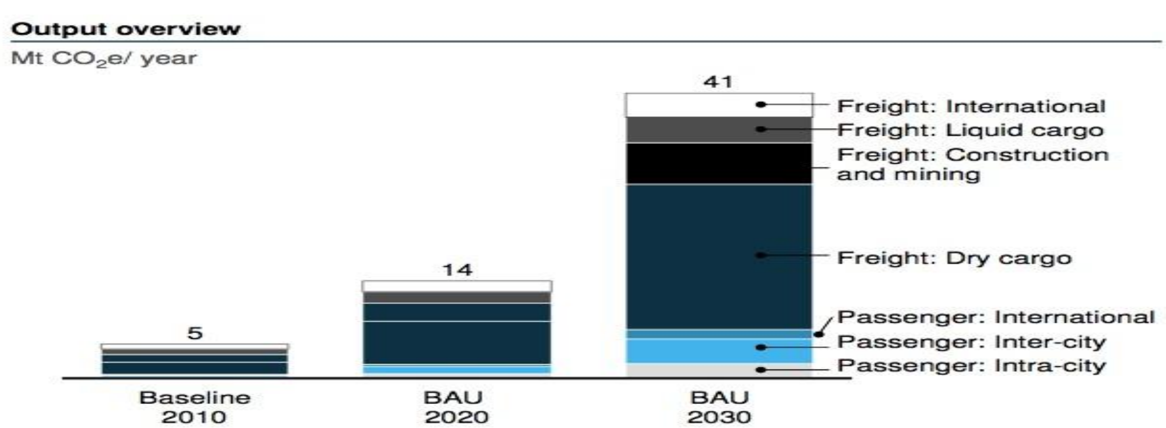
2.1.1.1. The Business as Usual Emissions Scenario

In 2010, the GoE profiled the national BAU GHG emissions projection to 2030. This profile shows that on the current pathway for economic development, countrywide GHG emissions will increase from 150 Mt CO_2e (2010) to 400 Mt CO_2e (2030) – an increase of more than 150%.

While the Ethiopian transport sector is small, and in 2010 accounted for only 3% of national GHG emissions, transport emissions are rising fast. Transport emissions arise predominantly from the fuel that is used to drive the various types of transport. Road transport – particularly freight and construction vehicles – accounted for 75% of Ethiopian transport emissions in 2010, and experience across the world suggests that without intervention to provide better transport alternatives, vehicle transport and related emissions will continue to grow.

Internationally, air transport is well known as being an intensive emitter of greenhouse gases – although there are a number of global industry initiatives to reduce emissions. International travel to and from Ethiopia forms the great majority of Ethiopian airport use, and in 2010 air transport contributed 23% of transport-related emissions (1.1 Mt CO_2e), a significant share.
Under the BAU scenario, Ethiopia's GHG emissions from transport will continue to grow and emissions from the transport sector will increase from 4.9 Mt CO_2e (2010) to 40.7 Mt CO_2e (2030). In relative terms, the transport sector will increase its annual emissions by around 11%.

FIGURE 8*: TRANSPORT SECTOR GHG EMISSIONS TO 2030 UNDER THE BUSINESS-AS-USUAL SCENARIO*



Source: CRGE (2011)

The increased emissions will be driven by higher freight transport emissions (+13% p.a.) and passenger transport emissions (+9% p.a.).

- *Freight transport*: The growing economy will increase the need for freight transport, leading to steep growth in tone-km of freight transported from 23 billion (2010) to 279 billion (2030), a growth of +13% p.a. Emissions will increase from 2 Mt CO_2e (2010) to 24.1 Mt CO_2e (2030). The BAU scenario assumes that the average fuel efficiency of the freight vehicle fleet will improve by 3.3% in this time period.
- *Passenger transport*: The increasing population, a strong urbanization trend and growing per capita GDP, will increase total travel measured in passenger-km from 40 billion (2010) to 220 billion (2030). Emissions will increase from 2.5 Mt CO_2e (2010) to 13.1 Mt CO_2e (2030). The BAU scenario assumes that the average fuel efficiency of the passenger vehicle fleet will improve by 10% in this time period.
- *Mining and construction*: Mining and construction transport activity will grow from 3 billion tone-km to 34 billion tone-km, increasing GHG emissions from 0.3 Mt CO_2e (2010) to 3.5 Mt CO_2e (2030). The BAU scenario assumes that the average fuel efficiency of the mining and construction vehicle fleet will improve by 3.3% in this time period.

The transport sector will continue to grow to meet continued demand and growing transport needs in Ethiopia as a key facilitator of economic wellbeing. Decoupling GHG emissions from the transport sector and economic growth, or at least lowering the GHG intensity of future transport growth, represents the key challenge to achievement of the CRGEs low-carbon targets and will require departure from the business-as-usual (BAU) scenarios in the transport sector.

2.1.2. Vulnerability of Transport Infrastructure to Climate Change

While the expected risks to Ethiopia's transport infrastructure are known, they have not been quantified, and a detailed vulnerability assessment has not been carried out for the sector as a whole or for any of its individual modes. The following *qualitative* illustration of potential vulnerability should be used to identify key areas for future development of a detailed, sector-wide, evidence based vulnerability assessment. Climate change is expected to have a significant impact on transportation, affecting the way transportation system is planned, designed, constructed, operated, and maintained. As part of this *qualitative* assessment, the significance of the primary climate drivers, temperature and precipitation, and their related variables, was assessed in terms of impacts on infrastructure design, operations and construction. Though each climate factor has implications for the transportation network as a whole, the relative significance of different climate factors varies as each of the three main sub-sectors – roads, rail and air – has very different types and ages of infrastructure.

To differentiate between the differing impacts levels, the likelihood of the impact and its consequences were taken into account. For each sub-sector the assessment reviewed how predicted changes in certain climate variables could impact infrastructure operations, using a graded *classification* system ranging from low to high impact that enables identification of the most vulnerable infrastructure and technical risks. To ensure consistency across the sub-sectors, the definitions of low, medium and high impact are based on the impact on infrastructure functionality and the likely geographic scale of the impact. Technical risks were considered in detail using a series of criteria, including:

I. The technical issue and its associated operational implications;
II. Speed of recovery from the impact;
III. Socio-economic effects;
IV. The likely timeframe for the issue compared with an elements' typical design life;
V. The distribution of the impact; and
VI. Whether the impact will cause a service failure or disruption.

TABLE 6: MATRIX OF DEGREE OF IMPACT DUE TO VULNERABILITY TO CLIMATE CHANGE

		Geographic Scale of Impact		
		Local	Regional	National
Impact on Infrastructure Functionality	No loss of functionality	Low	Low	Low
	Short term or minor disruption to service	Medium	Medium	High
	Severe impact or disruption to service/ failure of infrastructure	Medium	High	High

Impact classification:

- **Low** - Do not anticipate any loss of function of the infrastructure / no disruption in functionality from expected impacts.
- **Medium** – An impact is expected but is only associated with a disruption of service for a short period on a local basis. OR, there will be an impact but there are certain uncertainties that require additional work to be done.
- **High** – There is a risk of significant impact at a national scale or severe functionality disruption / failure.

The analysis focused primarily on the identification of impacts that will require an adjustment of current practices, to ensure that the existing service levels of the Ethiopian transport network and its assets are not compromised. It has not been possible to undertake threshold analysis as part of this assessment due to the gaps in knowledge and data within the sub-sectors as well as time constraints. Further work is required in this area to investigate critical tipping points for infrastructure. The assessment is therefore based on expert judgment and reflects the stakeholder consultations. It should be considered to be indicative rather than absolute. As increased technical information and knowledge is gained, additional benefit will be gained from reviewing how vulnerability will change over time.

2.1.2.1. Air Transport

Impacts that could affect the Design of New Infrastructure

Regarding the expansion or construction of airport infrastructure, particular attention should be paid to the rise in temperatures. In the design of airport buildings, the rise in temperature will be accompanied by a rise in energy demand for air-conditioning systems in terminal buildings, as well as for the maintenance of equipment in control towers and transmission stations. The rise in temperature could also result in the need for longer runways, since higher temperatures mean lower air density, a factor that reduces the thrust produced by aircraft and the wing's lift. The rising temperatures will also be accompanied by increased heat inside both airport service vehicles and passenger vehicles. This will mean a lower degree of comfort for users.

The impact of periods of increased heavy rainfall could also affect airport design, depending on size and design capacity. In addition, it is important to consider the impact of the increase in the intensity and frequency of extreme precipitation on the design of drainage systems, in order to prevent flooding of the airfield, and the potential impact of the wind factor on the design of the airfield, since current forecasts for changes in wind conditions are still uncertain, especially at the local level.

Impacts Affecting the Operation of Existing Infrastructure

The impact that climate change will have on the current airport network is particularly difficult to forecast due to significant information gaps. Impacts will vary depending on the airport's design, the characteristics of the airport traffic and local weather conditions. In addition, the impacts that currently affect airport operations most frequently and intensely are related to wind and a lack of visibility, phenomena for which there are few predictions are.

Severe weather events. It is possible that climate change will increase the current pattern and intensity of severe weather events that have the greatest impacts on aviation. These severe weather changes may be widespread geographically, profoundly affecting the operational aspects of aviation, overall air traffic and air space management, though predicting how the severe weather patterns will alter is uncertain.

- **Precipitation**. For aviation services, intense rainfall events as well as an increase in the probability of severe convective weather can be operationally disruptive. Weather is a critical influence on aircraft performance and the outcome of the flight operations during takeoff, landing and while aloft. In general, airlines, airports, and aircraft operate more efficiently in dry weather conditions. Precipitation decreases visibility, slows air traffic by requiring greater separation between aircraft, and decreases braking effectiveness. On the ground, effects include increased turbulence that affects engine thrust while runways, taxiways and aircraft parking areas are vulnerable to changes in precipitation, as drainage systems can be overwhelmed leading to flooding that in turn disrupts takeoff and landing operations. The climate models for Ethiopia indicate warmer temperatures with a likelihood of increased annual precipitation, especially an increase in the intensity of individual rainfall events.
    - The rise in the intensity of extreme rainfall may cause runway flooding, damage or disable air navigation aid systems and perimeter and ancillary installations, and cause damage due to flooding and saturation of drainage systems in some airports, all of which may result in more delays and flight cancellations. Increased flight cancellations and delay due to periods of increased heavy rainfall should also be expected.

- Implications of a drier climate to airport and aircraft operations include: Reduced aircraft and air traffic delays; reduced periods of wet surfaces on runways, taxiways, and aprons and an increase in the number of days of visual flight operations. A warmer, drier climate may also increase convective weather (turbulence) as well as increase the number and severity of thunderstorms.
- A wetter climate would reduce the number of visual flight rules (VFR) operating time periods. General aviation pilots would need to learn to fly in instrument flight rules (IFR) conditions by becoming "instrument rated," or not fly during periods of reduced visibility and precipitation.
- Intense precipitation episodes, combined with prolonged periods of drought, will generally result in the need for more maintenance work on the airfield drains to ensure they remain effective. Extended periods of drought may also lead to problems at airports where water is supplied by wells.

- **Temperature** increases seem to indicate that a small increase in the baseline runway length requirements will be needed (assuming other relevant factors are held constant).
  - *Runway design and utilization*: Runways are designed to accommodate the most stringent conditions aircraft can experience. Required runway lengths are a function of many variables, including airport elevation, air temperature, wing design, aircraft takeoff weight and engine performance, runway gradient, and runway surface conditions. As noted, the climate models project increases in temperature. Generally speaking, the higher the temperature, elevation and payload weight, the longer the runway needs to be to accommodate the aircraft. Initial runway construction planning typically takes into account a range of temperatures. This planned range may already capture the extent of the increase in mean maximum temperature derived from the climate models. If, however, increases in temperature exceed the planned range, then considerations for additional adjustment in runway length may be necessary, depending on other relevant considerations such as payload and elevation. In addition, runway surfaces are vulnerable to hot weather as the asphalt may soften. The greater frequency of very hot days will lead to greater need for maintenance of asphalt pavement (although some paving materials may handle temperature extremes better than others) and facility buildings and structures due to degradation in materials.
  - *Aircraft performance:* Aircraft are less efficient in hot weather, as there is less "lift" available, so aircraft movements must be more widely spaced. With the predicted increase in temperatures this is expected to become more frequent, leading to congestive delays. It is also possible that rising temperatures will influence aircraft performance. Current trends in aircraft design,

however, point to shorter takeoff distances, as airframes become lighter and engines more powerful. It is therefore possible that runway length requirements may actually decrease, even with increased temperatures, due to technological innovation. The trend from aircraft manufacturers is toward increased fuel-efficiency, more powerful engines and lighter weight aircraft and these could also offset the need for longer runway length.

- *Energy demand:* Terminal buildings are vulnerable to hot weather as they may overheat. The rise in maximum temperatures and heat waves will result primarily in greater energy demands for air-conditioning systems in airport buildings and aircrafts, a decline in the conditions of comfort for staff working on the runways and platform, and is likely to speed up the deterioration of bituminous materials in the airfield. The rise in the number of days with higher temperatures may also degrade air quality and jeopardize compliance with environmental regulations. Further, the risk of fire will increase in the airport reserve area and during aircraft refueling operations (given that the flashpoint of the kerosene fuel Jet A-1 is 38ºC). In specific cases, operating restrictions could be applied to the heaviest aircrafts due to the lack of runway length (higher temperatures lead to a reduction in the thrust produced, leading to a longer runway length required during takeoff).

- **Wind**. Wind is particularly important for airfield operations. Runway use is determined by the distribution of the wind in such a way that, as long as other factors allow it, the runway is aligned with the prevailing wind. The predicted increase and severity of storms may create a risk that airports have to close more frequently due to aircraft not being able to fly in such conditions. In the current weather conditions, wind causes Bole international Airport to close for an average of 15 days p.a. This is potentially a significant risk, and it is likely that in the relative short-term the number of closures at Bole International Airport will substantially increase. This loss of capacity will create severe disruptions as increased use is expected both for domestic and international travel.

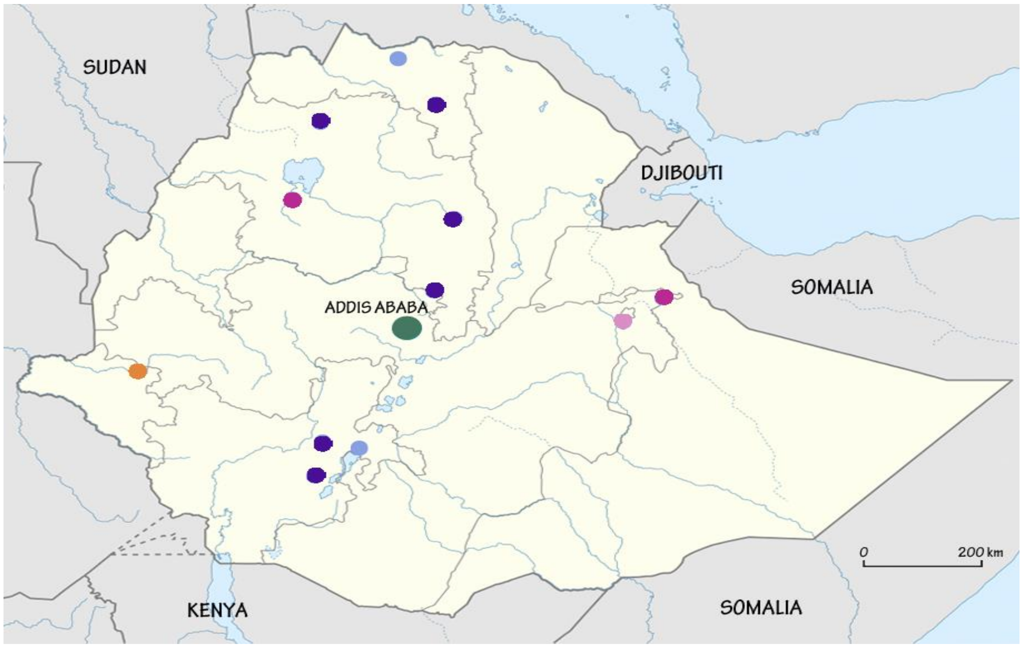
TABLE 7: AIRPORT VULNERABILITY MATRIX (RAINFALL, TEMPERATURE AND EXTREME EVENTS) IN THE TIME PERIOD UP TO 2030

Infrastructure & Elements		Rainfall	Temperature	Extreme Events
Runways	Technical risks	Medium	Low	High
	Operational implications	Medium	Medium	High
Pavements	Technical risks	Low	Medium	Low
	Operational implications	Low	Medium	Low
Drainage	Technical risks	High	Low	Medium
	Operational implications	High	Low	High
Aircraft	Technical risks	Medium	Medium	High
	Operational implications	Low	Medium	High
Terminal buildings	Technical risks	Low	Medium	Medium
	Operational implications	Low	Medium	Medium

Legend: Low Medium High

Assessment of airport locations against areas of known exposure to wildfire, flooding and precipitation driven landslides, presents an asset base at severe risk. Of the 18 domestic and international airports, all but 2 are at risk to one or more known climate related hazards, including all 4 critical airports. The immediate implication is that as the climate conditions change, the functionality of Ethiopia's air transport network will be severely hampered unless comprehensive action is taken to climate proof these assts.

FIGURE 9: INDICATIVE LOCATIONS OF AIRPORT INFRASTRUCTURE AT RISK



Legend: ● Airport not at risk; ● Airports at risk from flooding; ● Airports at risk from landslides & flooding; ● Airports at risk from landslides; ● Airports at risk from wildfires, flooding and landslides

2.1.2.2. Railway Transport

Impacts that could affect the Design of New Infrastructure

The impacts that will have the greatest effect on the design of new rail lines on the core network relate primarily to slopes with an expected increase in local damages. The main triggers will be the rise in intensity of short, extreme rainfall and more severe flash floods. These could affect the stability of slopes due to surface runoff and increased erosion.

More severe flash floods may affect the stability of the slopes at bridge abutments and undermine their pile foundations and protection elements. The stability of the slopes of embankments running parallel to rivers may also be affected.

Temperature: The level of projected average temperature increases is unlikely to require immediate design changes to track or other rail infrastructure, as these ranges generally fall within the current standards for existing rail track and facilities. However, the increase in temperature extremes – very hot days – could increase the incidence of buckling ("sun kinks") on rail tracks.

- *Design parameters:* The overall rise in temperature and thermal oscillations will cause expansion of the rail and increase its internal stress, affecting the strain on the track and fastenings.
- *Track buckling*: Temperature increases could raise the danger of rail buckling but would be unlikely to necessitate design changes. To minimize the compressive stresses from high temperatures and avoid track buckling, it is important to ensure that during installation, the rail is pre-stressed to a neutral temperature (i.e., there is no stress in the rails at that temperature. In most countries the neutral temperature is presently calculated at 27ºC or 75% of the expected maximum temperature of the region).
- *Energy demand:* With respect to railway stations and technical buildings, a major impact associated with increased temperature is an increase in air-conditioning needs. Increases in temperatures also are likely to increase energy consumption for cooling of freight transport. Air conditioning requirements for passengers also can be expected to increase, which may lead to a need for additional infrastructure at terminal facilities.

Precipitation: The impacts of increased precipitation are mainly associated with the rise in heavy rainfall and extreme rainfall events:

- *Earthworks and erosion:* In terms of earthworks, an important concern is the erosion of cut slopes by surface runoff and possible landslides. In the specific case of bridges, the increased erosion of pile and abutment foundations and the risk of collapse are cause for concern, as is the possible reduction of the freeboard between the water surface and the lowest point on a bridge due to the rising flash floods. In particular, there is an expected rise in the risk of erosion of cut slopes and embankments caused by heavy rainfall, a rise in the erosion of piles, abutments and protective structures on bridges and viaducts. As a result of the flow of flash floods, flooding and debris dragged by surface runoff in tunnels and cut-and-cover tunnels, and an increased risk of collapsing fences due to the combination of heavy rainfall and intense winds. Those bridges that are not founded on piles are most vulnerable to scour due to their foundations being undermined by the energy of the flooded river. Bridge failures will lead to significant disruption to services, increasing deployment of emergency personnel and unplanned remedial activities. Higher rates of erosion and railroad bridge scour will require redesign of storm water and drainage infrastructure, as well as higher safety risks and increased maintenance requirements.

Wind: Where overhead line equipment (OLE) on electrified lines are designed to a lower specification they are vulnerable to high winds that can bring down the lines and cause significant disruption to services.

Impacts during the Construction Phase

In terms of construction of rail infrastructure, climate change is expected to have a particular impact on some aspects of health and safety and risk prevention during construction. The rise in maximum temperatures and number of heat waves could affect working conditions and/or periods, and the operational and comfort requirements of construction machinery. It could also increase the risk of accidental fires during execution of the works. The increased intensity of occasional extreme rainfall in some areas could make it advisable to reinforce the drainage and protection systems, especially during the construction of sub grades and earthworks. As a result of climate change, it may also be necessary to change certain construction processes (e.g. the setting and curing of concrete as a consequence of the increased insolation) or use of alternative processes that consume less water due to water scarcity.

Impacts affecting the operation of existing infrastructure

Temperature: The overall rise in temperature and thermal oscillations will cause expansion of the rail and increase its internal stress, affecting the strain on the track and fastenings.

- *Safety:* The projected increases in average temperature and number of hot days, coupled with possible increases in humidity, will create serious safety concerns for workers in rail yards and other rail facilities and would require investments to protect rail workers. This might include increases in crew size to allow for more frequent recovery breaks or greater use of climate-controlled facilities for loading and unloading the railcars. Regardless of the solution, providing the necessary relief for workers will lead to increased operating or capital expenses, which will be reflected in higher transportation costs.
- *Track buckling*: Despite designed preparation, buckling can still occur and may become more frequent with the predicted higher temperatures. The likely result would be line closures, or possibly derailment. When the track buckles, the associated rails, sleepers and stone ballast (the

permanent way) become more vulnerable. The possibility of rail buckling can lead to speed restrictions to avoid derailments in certain seasons.

- *Energy demand:* With respect to railway stations and technical buildings, a major impact associated with increased temperature is an increase in air-conditioning needs.
- *Overhead Line Equipment (OLE)* on some electrified lines is vulnerable to high temperatures that can cause the line to break from increased stresses and result in significant disruption to services. The predicted increase in temperatures may increase this vulnerability. All overhead lines should incorporate a temperature resilient apparatus that allows for expansion.

Precipitation: The impacts of increased precipitation are mainly associated with the rise in heavy rainfall.

- *Erosion:* The primary impacts on rail infrastructure from precipitation are erosion of the track sub grade and rotting of wooden crossties. Erosion of the subgrade can wash away ballast and weaken the foundation, making the track unstable for passage of heavy locomotives and railcars.
- *Service incidents:* There is also an expected rise in the number of rail service incidents due to the presence of obstacles on rail platforms, local flooding and damage due to the heavy rainfall. In vegetated areas, a rise in the number of fires affecting rail traffic is also expected due to the increased number of heat waves and periods of drought.

Wind: Empty freight wagons can blow over in high winds, and in many countries rail services are cancelled if gusts of more than 128 km/hour are forecast. This is to minimize passenger discomfort and to reduce the risk of damage from falling trees and other debris.

TABLE 8: RAIL VULNERABILITY MATRIX (RAINFALL AND TEMPERATURE) FOR THE TIME PERIOD UP TO 2030

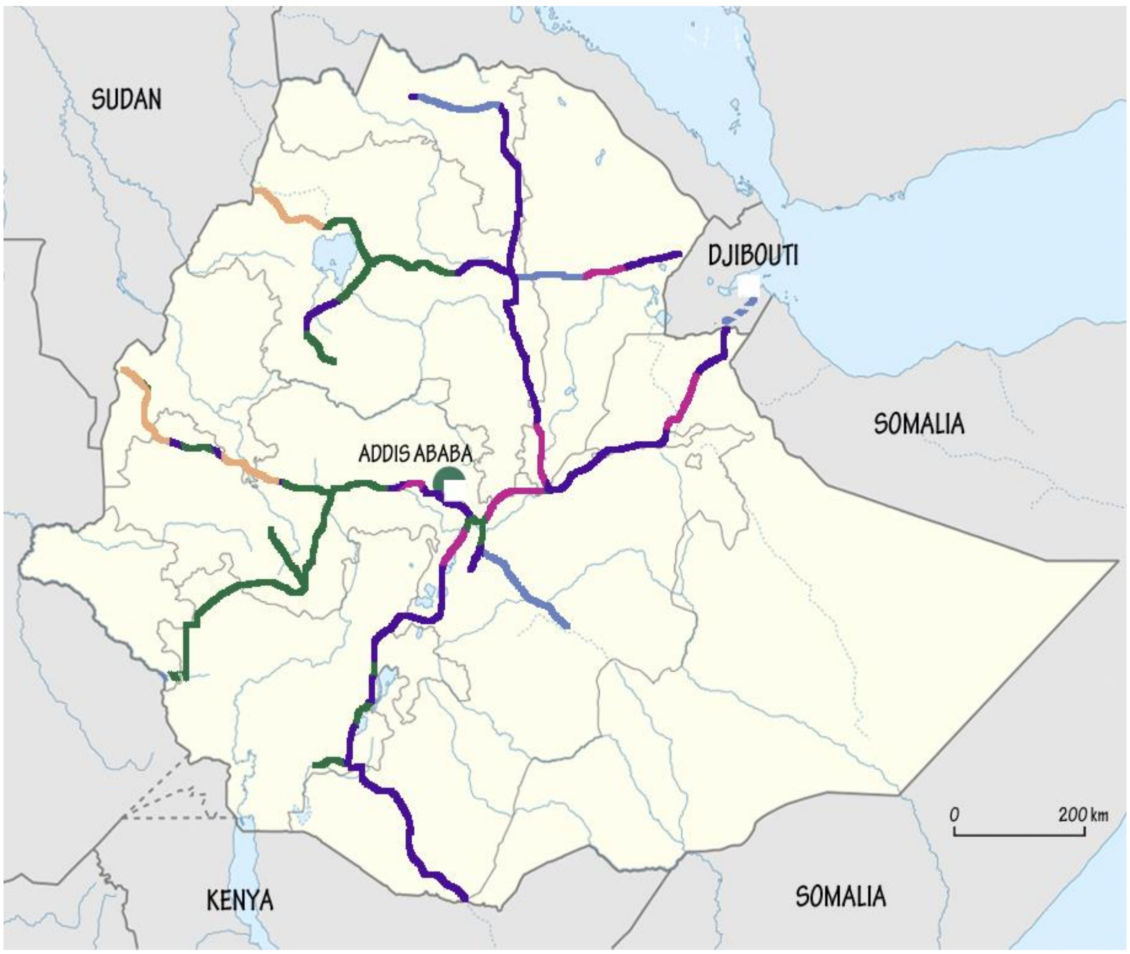
Infrastructure & Elements		Rainfall	Temperature
Track and ballast (permanent way)	Technical risks	High	Medium
	Operational implications	Medium	Medium
Structures	Technical risks	High	Medium
	Operational implications	High	Low
Drainage	Technical risks	High	Low
	Operational implications	High	Low
Earthworks	Technical risks	High	Medium
	Operational implications	High	Medium
Signaling	Technical risks	Medium	Low
	Operational implications	Low	Low
Overhead line equipment	Technical risks	Low	Medium
	Operational implications	Low	Medium
Trains (passenger & freight)	Technical risks	Medium	Medium
	Operational implications	Medium	Medium

Legend: Low Medium High

Assessment of rail line locations against areas of known exposure to wildfire, flooding and precipitation driven landslides, presents an asset base at medium risk. The two critical rail lines are at risk from both flooding and precipitation driven landslides. Construction of the majority of the remaining lines and line segments has not yet been completed which provides Ethiopia with the needed time to re-assess locations and climate-proof the design to prevent functional and operational issues as the rail network developed begins its operations.

In addition, the current and planned locations for the ICDs needs to be reviewed, as each and every one is located within or along a known hazard area, placing their ability to function at severe risk, and increasing the risk to the operational capacity of the rail network.

FIGURE 10: INDICATIVE LOCATIONS OF RAIL INFRASTRUCTURE AT RISK



Legend: ● Rail line not at risk; ● Rail line at risk from flooding; ● Rail line at risk from wildfires; ● Rail line at risk from landslides;

● Rail line at risk from landslides & wildfires

2.1.2.3. Road Transport

Impacts on the Infrastructure Planning Phase

In general, the impact that climate change may have on infrastructure planning tasks is considered limited compared to the possible impact on its design and operations. The two planning facets that may be most compromised by climate change *a priori* are traffic demand and the assessment of site suitability for the construction of new infrastructure. A secondary concern would be the planning of connectivity between the various transport modes.

Impacts that could affect the Design of New Infrastructure

The impacts that will have the greatest effect on the design of new roads relate primarily to slopes with an expected increase in local damages. The main triggers will be the rise in intensity of short, extreme rainfall and more severe flash floods. These could affect the stability of slopes due to surface runoff and increased erosion. More severe flash floods may affect the stability of the slopes at bridge abutments and undermine their pile foundations, protection elements and drainage infrastructure. The stability of the slopes of embankments running parallel to rivers may also be affected. The rise in temperatures and increase in droughts could make it necessary to select more resistant plant species for slope stabilization. Additional assets/components of the road infrastructure that may also be affected by climate change, though to a lesser extent, are pavements, road geometry, vegetation, bridges and protective structures, signing and barriers.

- *Road surfaces (Pavements):* The expected impact will be widespread. The greater frequency of very hot days will lead to greater need for maintenance of roads and asphalt pavement (although some paving materials may handle temperature extremes better than others) due to degradation in materials. Concrete road surfaces can also fail due to the expansion joints closing, which in certain cases can cause the slabs of concrete to lift up, and the road to be closed. The rise in maximum temperatures could lead to an increased risk of non-structural ruts and cracks due to the premature oxidation of the binder. A decline in the average annual precipitation could preclude the use of porous asphalt over a larger area of the country.
- *Design temperature:* The designs of steel and concrete bridges in Ethiopia are based on a maximum design temperature of 35ºC to 50ºC. In some countries, the maximum design temperature for bridges and pavements is 46ºC to 53ºC. It would be prudent to review the design standards and ensure that the projected increase in temperatures is smaller than these values and

to ensure that joints in steel and concrete bridge superstructures and concrete road surfaces can adequately accommodate thermal expansion resulting from these projected temperatures. Consideration should be given to designing for higher maximum temperatures in both replacement and new construction.

- *Bridges:* Bridge foundations across the road network are vulnerable to scouring from increased levels of rainfall and higher river flows that can lead to instability of the structure and in extreme cases, to failure and collapse. Those bridges on the road network not founded on piles are most vulnerable to scour. In addition, road bridges longer than 60m are typically designed with expansion joints. If the maximum design temperature exceeds the design one, these joints may fail as the expanding bridge decks could cause the joints to shrink beyond the design parameters. This could cause further damage to the bridge, usually resulting in road closures. Severance of access for communities due to bridge failures can lead to major disruptions, even local roads. The age of the majority of the bridges on the road network poses a unique opportunity for systemic improvements.
- *Road geometry:* In terms of the road geometry, a rise in the intensity of extreme precipitation may lead to an increasing number of locations where the drainage capacity of the road surface is insufficient, requiring a review of the design of the carriageway's drainage conditions, such as the transition of the super-elevation.
- *Drainage:* The rise in the intensity of extreme precipitation could lead to an increase in the number of locations where the drainage capacity of the road surface or bridge drainage systems is insufficient, resulting in aquaplaning problems or the accumulation of stones that fall onto the road from the hillsides and cut slopes. The intensity of the rainfall can also lead to high rates of runoff that overwhelms the road drainage system, resulting in ponging.

Impacts during the Construction Phase

In terms of construction of infrastructure, climate change is expected to have a particular impact on some aspects of health and safety and risk prevention during construction. The rise in maximum temperatures and number of heat waves could affect working conditions and/or periods, and the operational and comfort requirements of construction machinery. It could also increase the risk of accidental fires during execution of the works. The increased intensity of occasional extreme rainfall in some areas could make it advisable to reinforce the drainage and protection systems, especially during the construction of sub grades and earthworks.

As a result of climate change, it may also be necessary to focus on certain construction processes (e.g. the setting and curing of concrete as a consequence of the increased insolation) or use of alternative processes that consume less water due to water scarcity.

Impacts Affecting the Operation of Existing Infrastructure

Roads are the backbone of the transportation network in Ethiopia. At present, the federal road network is the main mode for transporting people across the country. Thus, impacts to the road network often serve as choke points to passenger and freight traffic that emanates in, or flows through, the road network.

In terms of the operation of existing infrastructure, the road assets that will be most affected will be earthworks and drainage.

- *Road embankments:* are vulnerable to wash away or landslides from either surface water runoff or from overflowing streams or rivers, as the high flows can scour and destabilize them. The impacts on earthworks are expected to be similar to those relating to their design stage and such failures will lead to major service disruption. With regard to drainage elements, the rise in the intensity of extreme rainfall could place greater demands on their capacity at local level, intensify the reservoir effect of some embankments or, combined with the concentration effect of many cross-drainage elements of roads, increase downstream erosion caused by water flows. A reduction in average precipitation, coupled with drier soils and less runoff will decrease soil moisture, resulting in a decline of slides in slopes adjacent to roads and highways. It also would mean less settling under pavements, with a decrease in cracking and undermining of road and pavement base courses.
- *Bridges and protective structures*: More intense extreme rainfall and flash floods are the main risks for bridges and protective structures; the rise in rainfall intensity could lead to an increase in local episodes of erosion to piles, abutments and retaining walls, and have an impact on piles due to debris deposits. Increases in extreme heat also have significant impacts. Maintenance and construction costs for roads and bridges are likely to increase as temperatures increases. It is likely that higher temperatures will cause some pavement materials to degrade faster, requiring

earlier replacement. Maintenance and replacement costs will likely grow as the number of days above 30ºC increases and as the projected maximum record temperatures increase.

- *Traffic safety*: Climate change may also lead to a rise in local impacts that could jeopardize the traffic safety and the accident rate of vehicles. An increase in the frequency of extreme precipitation events will result in more frequent short-term flooding and bridge scour, and culvert washouts. In general, severe weather events are correlated to higher incidence of crashes and delays, affecting both safety and mobility.
- *Signs and road markings*: The overall rise in maximum temperatures and number of heat waves will lead to an increase in sunlight exposure, which may affect the durability of certain signing elements due to the ultraviolet rays. The rising temperatures may also make road markings fade prematurely or cause the connecting elements in long stretches of metal safety barriers to break due to excessive expansion. The combination of heavy rainfall and intense localized winds may also reduce the stability of sign panels.

In terms of the transit vehicle operations on existing infrastructure, the projected impacts include:

- Given the temperature projections, the overall scheduled service may be disrupted due to temperature stresses on engines and air conditioning systems that could possibly affect vehicle and fleet availability rates. One of the most common causes of service disruption is vehicle breakdown due to overheating. These temperature-related maintenance costs will also impact the budgets of transit agencies and operators. For fleet vehicles, temperature increases, especially increases in the extremely high temperature range, will cause increases in the use of air conditioning on buses to maintain passenger comfort, exacerbating vehicle availability rates and raising fleet costs due to increased fuel consumption. Increases in temperatures also are likely to increase energy consumption for cooling for freight transport.
- The climate models point to location dependent potential increases or decreases in average annual precipitation. If precipitation and its intensity increase, it likely would lead to an increase in accidents involving buses, as well as increased congestion, costs and disruptions associated with such accidents.
- High-sided road vehicles and trucks are vulnerable to high winds, especially when crossing high bridges. With the predicted increase in stormy weather, they may become more vulnerable and have the potential to increase service disruptions.

TABLE 9: ROAD VULNERABILITY MATRIX (RAINFALL AND TEMPERATURE) IN THE TIME PERIOD UP TO 2030

Infrastructure & Elements		Rainfall	Temperature
Pavements	Technical risks	Low	Medium
	Operational implications	Low	Medium
Structures	Technical risks	High	Medium
	Operational implications	High	Medium
Drainage	Technical risks	High	Low
	Operational implications	High	Low
Earthworks	Technical risks	High	Medium
	Operational implications	High	Low
Transit (vehicles)	Technical risks	Low	Medium
	Operational implications	Low	Medium
Freight transport	Technical risks	Low	Low
	Operational implications	Low	Low

Legend: Low Medium High

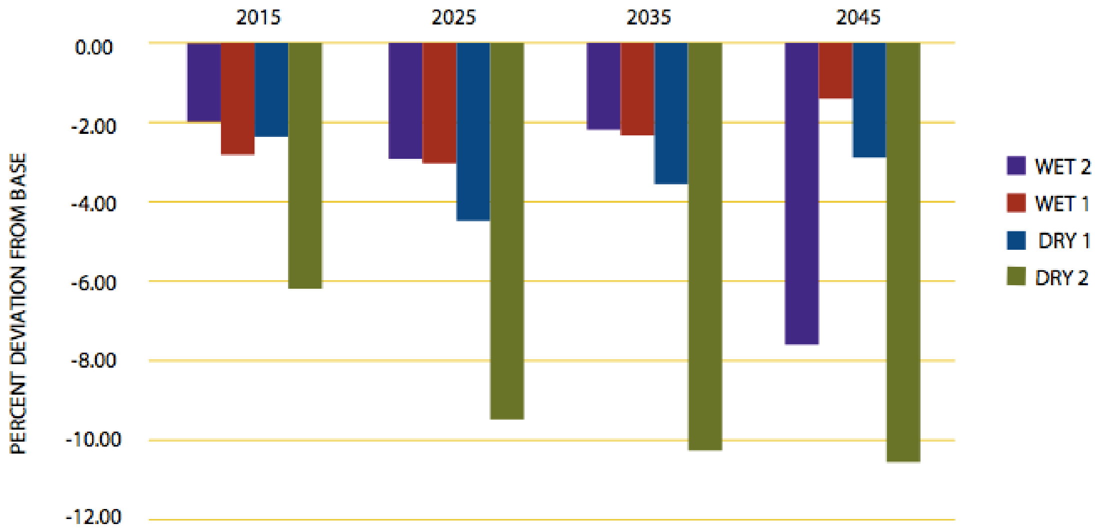
Assessment of road locations against areas of known exposure to wildfire, flooding and precipitation driven landslides show that the entire asset base is at medium–high risk. While road design standards have been reviewed recently there is an urgent need to review them once again against known climate parameters and assess the potential impact on both existing roads and the design of new roads. In addition, given that 38% of the bridges are more than 30 years old and 26% are more than 60 years and are towards the end of their design life, their urgent redesign with more stringent criteria is needed.

2.2. Projected Economic Impacts of Climate Change in Ethiopia

Assessment of climate impacts on transportation infrastructure relies on an understanding of historical climate trends and the established future projections. Adapting to a global climate that is about 2ºC warmer will be costly. The 2007 "Stern Review on The Economics of Climate Change" documented that the benefits of strong, early action on climate change considerably outweigh the costs. That study found that 1% of GDP p.a. must be invested in order to avoid the worst effects of climate change and that failure to do so could risk global GDP being 20% lower than it otherwise might be. The World Bank calculates the global cost of adapting to climate change at an average of 0.2% of projected GDP each year between 2010 and 2020 (for all developing countries) and at an average of 0.12% of projected GDP between 2040 and 2050. In terms of actual costs, this amount to an average of 70 billion – 100 billion USD each year (at 2005 prices) between 2010 and 2050. This global average obscures an uneven distribution of the burden of adaptation across regions and time. The estimates for the overall cost of adaptation are 0.6 – 0.7% of GDP for sub-Saharan Africa between 2010 and 2020, falling to about 0.5% of GDP in 2040 – 2050. Apart from sub-Saharan Africa, the regions facing high relative costs of adaptation are the Latin America and the Caribbean, and the South Asia under the dry climate scenario. The absolute costs of adaptation increase over time and will certainly continue to increase after 2050.

Under a drier climate, losses are large (6 – 10% of GDP) and regularly distributed between 2010 and 2050. In contrast, under a wetter climate, the GDP losses accelerate after 2030 because of the costs of coping with climate impacts, and the 10-year average GDP for 2040 – 2050 is expected to be lower by nearly 8% than in the 2010 baseline. These numbers highlight the high degree of vulnerability of the Ethiopian economy to the future climate shocks.

FIGURE 11 : PROJECTED IMPACTS OF THE FOUR GCM CLIMATE SCENARIOS ON THE 2010 BASE GDP



Source: World Bank (2010)

The analysis for Ethiopia shows that the Ethiopian economy is already affected by climate change and that there are three major conduits to these impacts:

(a) Agriculture, which currently accounts for 42% of Ethiopian GDP, is highly sensitive to seasonal variations in temperature and moisture;

(b) Roads, the backbone of the country's transport system, that are often hit by large floods, causing serious infrastructure damage and disruptions to supply chains; and

(c) Dams that provide hydropower and irrigation and are affected by large precipitation swings.

When designing new infrastructure, there will be a need to switch from designing with standards developed for historic climate trends to designing for future (and uncertain) climate projections – many elements of transportation infrastructure are sufficiently long-lived that it may not be prudent to plan and design based on historic averages.

As part of the World Bank analysis, the road inventory in Ethiopia was reviewed, and preliminary cost impacts of climate change calculated. Based on these calculations, it is estimated that maintenance on paved roads that is directly attributable to temperature change ranges from 5 million-13 million USD per year depending on the climate model used. Similarly, the increased maintenance cost for unpaved roads is estimated between 2 million-14 million USD per year. In contrast to the paved roads that could see reductions in maintenance costs (due to enhanced design standards), the unpaved roads continue to see rising maintenance costs that are dependent on the climate scenario due to limited options in making these roads resistant to climate change impacts. Overall, the total increase in maintenance costs due to temperature increases is estimated to be between 15 million-31 million USD per year depending on the climate model used. These numbers are on the lower range of what may be expected due to the key assumptions regarding regular maintenance and not including the costs of changes in rainfall levels.

TABLE 10: CUMULATIVE CLIMATE CHANGE IMPACT ON PAVED AND UNPAVED ROADS BASED ON INCREASED ROAD MAINTENANCE COSTS FOR THE GCM WET 2 AND DRY 2 CLIMATE SCENARIOS (IN MILLION USD)

Roads	Wet 2	Dry 2
Cumulative cost increase for maintaining paved roads	849.2	538.4
Cumulative cost increase for maintaining gravel and earth roads	408.8	308.7
Total cumulative maintenance costs from climate change (paved and unpaved roads)	1,258	847.1

Note: The GCM models Wet 2 (wettest climate) and Dry 2 (driest climate) show the widest variations from the current climate
Source: World Bank (2010)

If the road design standards are modified, then the direct benefits in terms of increased lifetime of roads designed with higher standards outweigh the corresponding costs in a discounted benefit/cost analysis irrespective of climate outcomes. The benefit/cost ratio of adopting higher design standards is 17-75% higher than in the baseline under a wetter climate and 16-55% higher under a drier climate.

2.3. Establishing the Climate Risk Baseline for Transport Infrastructure

In general, the climate variables that are relevant to assessing climate risks to the transport sector are known, though detailed information may still be missing on some of the relevant variables. Climate data, however, are constantly evolving and it is expected that the required information on these details will be refined over time. For the purposes of developing the Climate Resilient Transport Sector Strategy and the policies, that will flow from it, the known variables have been mapped to the transport sector based on the available information.

TABLE 11: CLIMATE VARIABLES RELEVANT FOR THE TRANSPORT SECTOR IN ETHIOPIA

Climate Variables		Roads	Rail	Air	Expected Climate Risks
Air temperature	Mean temperature	●	●	●	The estimated *mean temperature* projections indicate that all Ethiopian regions will experience a gradual increase in the average surface temperature and changes in temperature extremes (around +2°C in summer and +1.2°C in winter every 30 years). The *daily maximum temperatures* and *daily minimum temperatures* will also increase. There will also be a tendency towards a slight increase in the *diurnal thermal oscillation,*[2] especially in inland areas in the summer months. In all regions of Ethiopia, there will be a significant rise in the intensity and frequency of extreme temperature events. The duration of *heat waves* in a given year is set to double by 2050.
	Daily maximum temperature	●	●	●	
	Diurnal thermal oscillation	●	●		
	Heat waves	●	●	●	
Cloud cover and cloud ceiling				●	There is insufficient information to outline the trend for the changes in cloud cover, cloud formation, dissipation and radiative properties, and the cloud ceiling for Ethiopia. Global data, however, indicates a slight increase in cloud cover in all regions and at all times of the year.
Precipitation	Mean annual precipitation	●	●	●	Increased *variability of annual precipitation* is expected (a reduction in rainfall of 25% to an increase of 30%).A general increase in frequency, intensity and length *extreme precipitation* with a very short duration is expected, leading to increased risk of local *flooding*
	Intensity of extreme rainfall	●	●	●	
	Duration of heavy rainfall	●	●	●	
	Floods	●	●	●	
	Droughts	●	●		Ethiopia is highly vulnerable to drought and it is considered the single most important climate-related natural hazard impacting the country's economy

[2]Diurnal thermal oscillations the difference between the maximum and minimum temperatures during a given day

Climate Variables		Roads	Rail	Air	Expected Climate Risks
Flash floods		●	●	●	A general increase in frequency, intensity and length *extreme precipitation* with a very short duration is expected, leading to an increase in the frequency of *flash floods*
Water table		●	●	●	There is insufficient information to outline the trend for the changes to the hydrological regime.
Wind	Intensity of extreme winds	●	●	●	Significant changes in the intensity of surface winds are not expected.
	Frequency of strong winds	●	●	●	
	Wind direction	●	●	●	
	Wind direction variability			●	

CHAPTERTHREE

3.1. The Path Forward to Low Carbon and Climate Resilient Transport Sector

The CRGE's main objective is achievement of middle-income status through sustainable economic growth. Overall, the CRGE identified four sectoral pathways that will support Ethiopia's developing green economy. These sectoral pathways are focused on agricultural and land use efficiency measures, increased GHG sequestration in forestry, increased use of renewable and clean power generation and increased use of advanced technologies in industry, transport, and buildings. More specifically for the transport sector, the CRTS strategy expects to reduce significantly Ethiopia's dependence on imported fuels and cut transport based carbon emissions significantly by 2030.

In the transport sector, the GoE sees multiple opportunities to decrease emissions and 'jump start' the development of sustainable transport. The climate resilient transport sector strategy also envisages the contributions of the transport sector to the resilient development pathway through:

- Introducing stricter fuel efficiency standards for passenger and cargo transportation
- Impose age limits for second hand used vehicles imported.
- Promoting hybrid and electric vehicles to counter the low efficiency of the existing vehicle fleet;
- Constructing an electric rail network – powered by renewable energy – to substitute road freight transport;
- Improving urban transport in all urban centers of the country by introducing urban electric rail, light rail transit, introduce bus rapid transit, and improve bus operation system.
- Substituting imported fossil fuels with domestically produced biodiesel and bio-ethanol.
- Promote walking and cycling in all urban centers.

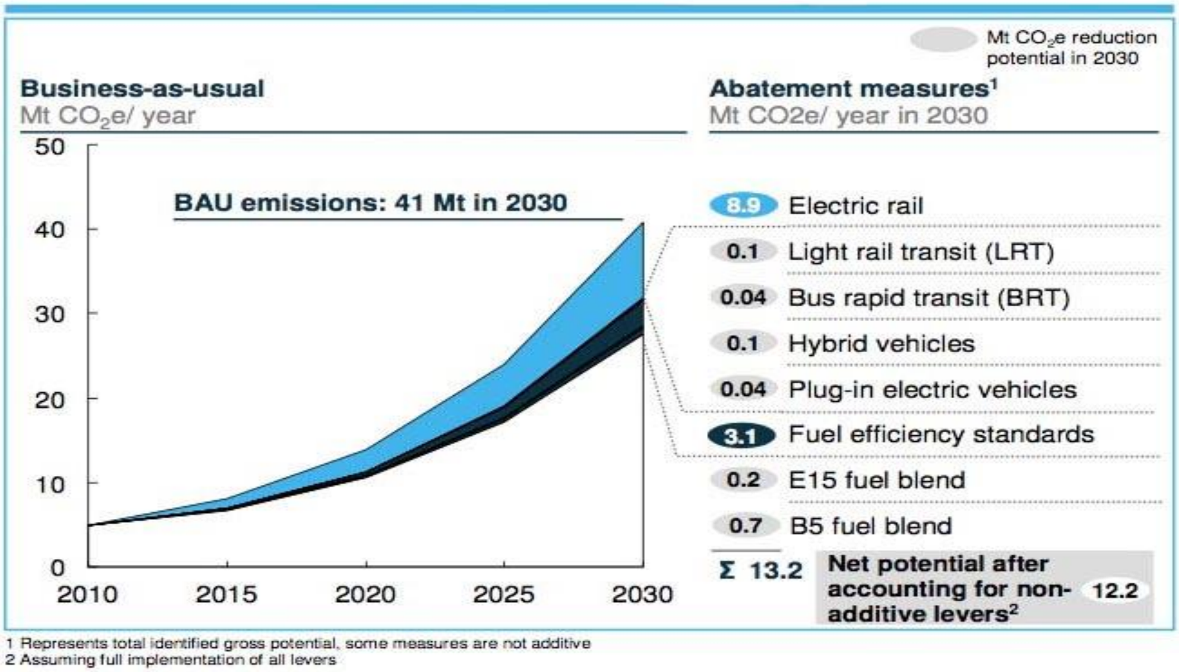
The CRTSS emphasizes the need to make investments in the transport sector that can contribute to an increase in the modal share of cleaner transport modes — urban transport, rail and inland transport — not only because of GHG considerations but because it also makes sense when confronting issues such as safety, congestion and overall efficiency of Ethiopia's transport system.

The GoE identified four categories of abatement levers for the transport sector: improving the public transport system in all urban areas of the country, improving vehicle fuel efficiency, changing the fuel mix and constructing an electric rail network for efficient freight transport. Leapfrogging to new technologies in transport offers a combined abatement potential of up to 13.2 Mt CO_2e by 2030. Based on the projected assumptions, the largest initiatives, with the greatest abatement potential, are the construction of an electric rail network (8.9 Mt CO_2e) followed by the introduction of fuel efficiency standards for all vehicles (3 Mt CO_2e). This assumes completion of the construction of more than 5,000 km of rail tracks and enforcement of new fuel efficiency standards for 30% of passenger vehicles and 10% of freight vehicles by 2030. The introduction of bio-fuels (ethanol and biodiesel) also forms a priority, though its abatement potential is much lower -1 Mt CO_2e.

The abatement potential of four of the transport sector's green growth initiatives have been calculated as follows:

- Improving Addis Ababa public transit by building a light rail transit system and establishing a bus rapid transit system: an abatement potential of approximately 0.1 Mt CO2e;
- Improving vehicle efficiency by enacting fuel efficiency standards: an abatement potential of approximately 3.1 Mt CO2e;
- Changing the fuel mix using a combination of adding biodiesel to the diesel mixture, increasing the amount of ethanol in the gasoline mixture, and promoting the adoption of hybrid and plug-in electric vehicles: a combined abatement potential of nearly 1 Mt CO2e; and
- Shifting freight transport from road to an electric rail network would eliminate emissions from the largest source of transport emissions. Shifting freight from road transport using diesel vehicles to rail transport powered by renewable electricity has an abatement potential of 8.9 Mt CO2e.

FIGURE 12: TRANSPORT ABATEMENT POTENTIAL IN THE YEAR 2030



Source: CRGE (2011)

Fuel efficiency standards seem to generate most of the cost savings (220 USD per ton of CO_2e). While electric rail generates some cost savings (91 USD per ton of CO_2e), the introduction of ethanol and bio-fuels is relatively cost neutral. Implementing all the transport levers by to 2030 will require investments totaling 23 billion USD. This cost is comprised almost entirely of capital expenditure.

3.1.1. Low carbon development path

3.1.1.1. Responding to the climate change

To ensure that the CRTSS's vision is fully implemented there is a need to ensure that the transport sector develops a cohesive approach to moving forward while employing the most beneficial means with the widest social implications.

The responses available to address the implications of climate are generally characterized as:

- **Adaptation:** Adaptation to climate change involves actions to help reduce vulnerability to the effects of climate change. In relation to transport infrastructure, adaptation involves actions that ensure that the infrastructure can better withstand the physical impacts of climate change.
- **Mitigation:** Climate change mitigation involves action to reduce the concentration of GHGs by limiting their sources (or by increasing carbon sinks). Mitigation action in the transport sector involves action to reduce the volume of emissions resulting from the use of road, rail, shipping and air transport.

As the climate changes, the strategies that Ethiopia will need to employ include both climate adaptation and mitigation (i.e., reduction of GHG emissions). The CRGE is focused on the mitigating the GHG emission aspects of economic growth, but no matter how much GHG emissions reductions are undertaken, some changes in climate are unavoidable. In addition to the direct effects on transportation infrastructure and services, climate change will catalyze changes in the environmental, demographic, and economic conditions within which transportation agencies conduct their work. In the long run, these broader changes may have very significant secondary impacts on the transportation sector that will need to be examined as part of the planning process. For example, changes in population centers induced by shifts in weather conditions will affect travel demand. As regions of agricultural production shift, freight flows may likewise change. Proactive adaptation planning can help limit the damage caused by climate change and reduce the long-term costs of responding to increasing intensity and growing numbers of climate-related impacts in the upcoming years. In this context, climate change has two main implications for the transport sector:

- **Risks for transport infrastructure:** Climate change poses risks for transport infrastructure. The physical effects of climate change can pose particular challenges for transport infrastructure. While the impact of climate change on transport infrastructure may vary depending on local factors, including the type of infrastructure in question, its location, design, age and relative usage, there will be consequences for most regulators, owners, operators and users of transport infrastructure.
- **Contribution to GHGs:** Worldwide, higher concentrations of GHG have been linked to a range of physical phenomena associated with climate change, including higher temperatures, sea level rise and flooding, lower rainfall, drought, increased intensity of storms and wildfires. In 2010, transport contributed approximately 3% to Ethiopia's total GHG emissions, 75% of which are

attributable to the combustion of fuel for road transport. In moving forward, the challenge will be to reduce the contribution that transport makes to Ethiopia's emissions problem without sacrificing sectoral development.

3.1.1.2. Reducing transport's contribution to GHGs emission (mitigation measures)

Transport activity typically grows in parallel with economic activity and while the growing contribution of transport to the climate change problem presents many challenges for the sector, there are opportunities to mitigate (or reduce) transport emissions. Most of the available measures and actions are specific to particular transport modes and focus on the avoid-shift-improve paradigm, some, however, relate more generally to the way in which transport services are used, to the impact of transport infrastructure design and its associated usage.

For consistent and long-term progress, however, climate change mitigation in the transport sector has to be seen in a broader context: sustainable transport should limit GHG emissions from transport and minimize other externalities such as pollution and congestion, without compromising economic growth.

3.1.1.2.1. Air transport

Reducing emissions from air transport poses significant challenges over the medium-term. While medium-term mitigation of CO2 from the aviation sector could come from improved fuel efficiency, such improvements are expected to only partly offset the growth of aviation related emissions, with the amount of CO2 emissions projected to grow by 3- 4% annually, at a global level. A number of policy options are available to reduce the pace of GHG emissions growth, as detailed below.

- **Emission Capping**: There are several successful air transport emission-capping programs in airports around the world, and at least 440 airports are known to be participating in these programs. The United Kingdom has one of the most successful programs in place since 2009. The program is based on a 2050 assessment of the maximum increase in air transport demand compatible with the country's carbon reduction emission targets for 2050, from both domestic and international flights. Projections on growth of demand and emissions were made assuming no carbon price constraining demand, and no limits were placed on airport capacity expansion. Since then, carbon emissions have been reduced mainly through: (a) Support for modal shift from aviation to rail for up to 300 km; (b) improvements in fleet fuel efficiency of 0.8% p.a. up to 2050 (for a total reduction of 30% by 2050); and (c) use of at least 10% bio-fuels. Hong Kong is another location with a successful emission-capping program. That program is based on a 25% airport-wide operational emission reduction every 7 years (i.e., 25% reduction in 2008 emissions by 2015) that applies to all aspects of airport operations. The base measurement unit used in the program is 1 workload (i.e., 1 passenger or 100 kg cargo).

- **Emissions Trading Scheme** (ETS): Participation in an emission-trading scheme such as the one instituted for the European Union (EU). The EU has imposed a cap on carbon emissions from all domestic and international flights from or anywhere in the world that arrive or depart from an EU airport, by including air transport in the ETS starting from 2012. The EU ETS started in January 2005, covered in the past only energy intensive industrial installations and like any ETS the emission level to be achieved is set and the market determines the price of carbon. Airlines will receive tradable allowances covering a certain level of carbon emissions from their flight per year, and after each year operators must surrender a number of allowances equal to their actual emissions in that year. If the airlines anticipate that their emissions will exceed their allowances, they can buy additional emission allowances on the market or adopt measures to reduce emissions for example, investing in technologies that more efficient.
- **Jet fuel taxation and other environmental charges**: At present, although it is possible for a fuel tax to be levied on domestic flights, it is difficult to do so for international flights due to legally binding commitments made in air service agreements. These agreements are expected to be renegotiated over time and jet fuel taxation could be a long-term option. A number of airports apply emissions or noise charges, which would need to be cost-effective and not duplicate emission trading.
- **Surface emissions, terminal and technical support facilities and infrastructure:** Though relatively minor in comparison to actual air travel related carbon emissions, there are a variety of opportunities for carbon emission reductions including: aircraft activity in terminal area; airline and other tenant vehicles, ground service equipment and electricity usage; ground access vehicles for staff and passengers, including buses and trains; electric ground support equipment like bag tugs and belt loaders; natural gas refueling stations for airport buses and shuttles; gate electrification; green practices within terminal buildings; energy efficiency measures such as pre-

conditioned air systems for aircraft at parking standing and solar energy and light bulb replacements for terminals.

- **Other measures:** Other policies aimed at controlled emissions from air transport include:
  A. technological improvements (aircraft renewal and replacement and retrofitting aircraft), including use of fuel efficient aircraft, such as through advanced propulsion systems, utilization of lightweight materials, and improved aerodynamics and airframe designs;
  B. improved air traffic management and airport operation procedures, including single-engine taxi to and from the runway and the use of a Continuous Descent Approach that can significantly reduce emissions during operations in and around an airport and navigation systems and air traffic control techniques that minimize fuel use and idling.
  C. usage of alternative fuels, such as lower carbon fuels and bio-fuels.

The specific reactive strategies for air transport are-

There is a clear need for a major expansion in air services between Ethiopia and key international hubs, and within Ethiopia, to support the proposed growth in economic and commercial activities. The facilities at Bole International Airport and the domestic airports in other parts of the country will require expansion and upgrading.

The introduction of domestic aviation services is a key element of the strategy to promote development, and integrate the remote districts into the economic mainstream and increase accessibility opportunities for some of the more distant areas.

The aviation sector reactive strategy comprises seven main activities:

- Expansion of international links with other hubs and regional centers;
- Provision of air carrier services and airport facilities sufficient for growth targets;
- Availability of domestic scheduled services linking main population centers;
- Construction of airstrips in remote areas for short takeoff and landing and helicopter services;
- Provision of helicopter services for search and rescue, emergencies, and charter services;
- Private sector participation in services and facilities; and
- Effective regulation and compliance with international safety and environmental standards.
- Applying land-use planning and management policies around airports in the country
- Improve Air Traffic Management (ATM) to achieve substantial fuel saving and emission reduction.

- Apply integrated measures embracing technology improvements, appropriate operating procedure, proper organization of air traffic and the appropriate use of airport planning.

Over the life of the Strategy, air transport should focus on improving both international and domestic services. Improvements in domestic services are crucial to help bridge the gap of distant rural access, when compared against rail and road access to some locations.

From a low-carbon perspective, the air transport and aviation services should focus on reducing or offsetting emissions of GHG produced as much as possible, with the following possible targets:

- Improve fleet fuel efficiency of 0.8% p.a. up to 2030;
- Introduce use of bio-fuels, up to 10% of mix; and
- Introduce operational and surface, terminal and technical support facilities emission reductions of 20% every 7 years.

3.1.1.2.2. Railway transport

Rail has the smallest carbon impact of the three main transport modes in Ethiopia. Increased investment in rail infrastructure would decrease carbon emissions and could have additional benefits, such as driving growth in regional areas that were previously not easily accessible.

Ethiopia is expanding its rail network with electrified lines that provide additional emissions reductions and energy efficiency. It is also expected that the largest reductions would come from the growth of intermodal transport, with a shift from road to rail. Even though rail transport is more energy efficient than other transport modes, improving energy efficiency is an important mechanism to reduce contributions to climate change further as well as to save costs. The main opportunities for mitigating GHG emissions associated with rail transport, after electrification, are improving aerodynamics, reduction of train weight, introducing regenerative braking that recover energy from power generation when braking and on-board energy storage, mitigating the GHG emissions from electricity generation and traffic management. Of the various technical options available, the one with the highest impact is likely to be regenerative breaking, followed by energy efficient driving techniques.

Apart from investment in rail infrastructure as an alternative travel mode, there is a range of technical solutions that could improve the energy efficiency of rail transport and reduce emissions. These include technical solutions aimed at achieving optimum train mass and operational changes, such as energy efficient driving and efficient matching of rail stock to demand. The rail industry, like the automotive sector, is also exploring the potential of new and emerging technologies; including hybrid drives and hydrogen fuel cells, (although as with cars there remains the issue of precisely how hydrogen is produced). In the long term, these advances may help significantly improve the environmental performance of rail.

By far, rail transports' biggest contribution to GHG emission reduction is promoting intermodal transport and modal shift from road. Increased usage of combined or intermodal transport, by, for example, taking a container off the road and putting it on a long-distance freight train and using trucks for short pre-and post-rail transport can cut energy consumption by almost half. As heavy trucks account for around 75% of freight journeys this represents a huge potential to integrate railways to modern, efficient, logistical chains, enhancing economic competitiveness while at the same time reducing road congestion and the negative environmental effects of road transport, particularly in relation to CO_2. Supporting the modal shift from road to rail will require making the rail mode more attractive (pricing road externalities is part of the equation). It will also require improving the operational performance of the rail undertakings and, especially relevant in countries with small network sizes, reducing delays in border crossing points. In this sense, policies that encourage modal shift to rail are the same set of policies required to sustain a competitive rail transport sector.

The specific reactive strategies for Railway transport are:-

The overall goal of the development of the rail network is to facilitate trade movement between Ethiopia and other countries in the region through measures to improve transit and customs procedures, together with parallel strategies to improve international road, rail, and air transport links. The strategy aims to reduce transport costs and travel times between Ethiopia and other countries in the region through improved infrastructure, easier transit and customs procedures, and implementable transport and transit agreements. The main activities required to implement the strategy and achieve these objectives include the continuing development of trade, transport, and transit agreements with neighboring countries; enhanced access to better road network; and improved facilities at border crossings.

Over the life of the Strategy, rail transport should focus on expanding the rail network, establishing multi-modal interchanges, and increasing the percentage of rail in the use mix for both freight and passenger services.

Ethiopia's approach to development of the national and urban rail network is already based on an energy efficient approach with the use of electrified lines. To further increase the rail sub-sectors' support to achievement of the CRGEs carbon emission targets, apart from investment in rail infrastructure as an alternative travel mode,

- There should be increased focus on introduction and use of technical solutions to improve the energy efficiency including achieving optimum train mass and operational changes, such as energy efficient driving and efficient matching of rail stock to demand,
- Improving rail aerodynamics,
- Reduction of train weight and introducing regenerative braking that recover energy from power generation when braking and on-board energy storage. This additional focus on energy efficiency should strive for a 20% emission reductions by 2030.

3.1.1.2.3. Road transport

Of the three main transport modes, road transport is by far the most significant contributor of GHG emissions. Accordingly, most of the mitigation initiatives that have been developed are directed at road transport. The initiatives consist of a mix of regulatory measures, financial incentives and voluntary programs:

Regulatory measures. The range of regulatory measures to reduce greenhouse gas emissions from road transport include:

- *Fuel efficiency and emissions standards:* are considered one of the most cost effective measures across all sectors to improve the fuel efficiency and reduce GHG emissions. In most countries, these types of standards have become progressively tighter over the years, though they have for the most part, been focused on air pollution and noise. Three quarters of vehicles sold globally are already subject to some form of energy efficiency and emission standards (i.e., fuel economy, CO_2, GHG) in major vehicle markets, and there is widespread support for increased harmonization of these types of targets. Key factors when introducing, or reforming, vehicle emission standards are the availability of vehicle fleet data and import-export characteristics, as well as enforcement considerations.

- *Fuel consumption labeling:* Under mandatory standards for fuel consumption labeling, a model-specific fuel consumption label must be placed on the windscreens of all new vehicles up to 3.5 tone gross vehicle mass. The label indicates how many liters of fuel a vehicle will use to travel 100 km and how many grams of CO_2 the vehicle would emit for each km. The rating on the label is based on standard test procedures that allow the performance of different models to be compared under identical conditions. The rationale for this type of initiative is to encourage consumers to factor in fuel efficiency and GHG into car purchase decisions.
- *Vehicle registration tax:* The collection of a vehicle registration tax can be linked to GHG emission reductions in different ways. In the Netherlands, for example, this tax is equal to 45% of the selling price of a vehicle and provides a discount or overcharge based on CO_2 emissions. In Norway, the vehicle registration fee is designed to make large-engine sports vehicles costlier through the payment of a GHG tax as a function of the hydro-fluorocarbon (HFC) content in the vehicle's air-conditioning system. When combined with high fuel taxes, the overall impact is to reduce both motorization rates and vehicle usage.

Incentives: Regulatory measures to reduce emissions from the transport sector are complemented by incentives that are directed predominantly at vehicle users.

- *Green or cleaner car rebates and incentives:* These types of incentives entitle vehicle owners who trade-in their old vehicles for new fuel-efficient vehicles to a rebate once the original vehicle is scrapped (that is, it cannot be re-sold). The objective of the program is to encourage owners of older vehicles that are less fuel-efficient and, therefore, more carbon-intensive, to replace those vehicles with more fuel-efficient models.

Road pricing instruments: Road pricing represents one of the key transport policies to reduce demand by raising the relative price of vehicle use to alternative mass transit in cities or other modes outside of urban areas. Efforts to model the potential effects of pricing policies on GHG emissions in transport require significant amounts of information as pricing strategies may affect:

(a) The number and type of vehicles owned by a household;
(b) Where people live and work;
(c) The number of trips they take;
(d) The time of day trips are taken;
(e) Whether they choose to drive or another transport mode; and

This means that the impacts of road pricing on GHG emissions depend on each of these factors over time and the resulting impact on vehicle-kilometers travelled and Vehicle operating conditions. These comprehensive analytical approaches to quantifying transportation and GHG impacts are both data and resource intensive, thereby limiting their use for most countries.

- *Fuel pricing* is a particularly effective policy instrument in that it can discourage vehicle usage — although this is a function of the short, medium, and long-term price elasticity of demand — and encourage the purchase of more fuel-efficient vehicles, thereby reducing vehicle-fuel intensity. In general, high fuel tax countries are associated with much lower levels of vehicle usage than in low fuel tax countries. Fuel taxes are relatively inexpensive to collect, easy to administer and reasonably equitable, since the charge is broadly proportional to road use. They do not however discriminate between road type, location of the road or time of usage. On the latter point, this means that fuel taxes cannot tackle the issue of high externalities associated with congestion. Another weakness is that they do not fully reflect the additional damage done and road space demanded by heavy vehicles (although heavy vehicles consume more fuel per km and, therefore, pay more in tax per km travelled, this is not proportional to their higher impact in terms of road surface damage). Shifting the tax burden to pollution and pollution-generating activities creates an incentive to use less energy. In a number of countries, the motivation for increasing fuel taxes is also to capture the damage to road infrastructure.
- *Toll road pricing:* Tolls have been generally used for specific roads, bridges and tunnels, although increasingly they are being introduced for networks. There are two main types- a closed toll system, where any vehicle entering the facility collects a ticket and pays a graduated fee at the exit point. The introduction of such a system requires that the road be fully 'closed' so no user can gain access to the road without collecting the ticket and paying the toll. The level of facilities required increases, and provision of a free alternative route is usually mandated. Open road tolling, also known as free-flow tolling, is the collection of tolls without the use of tollbooths. The major advantage is that users are able to drive through the toll plaza at highway speeds without having to slow down to pay the toll. Open road tolling may also reduce congestion at the plazas, and hence GHG emissions, by allowing more vehicles per hour per lane. A disadvantage is the increased risk of violators who do not pay. Collection of tolls on open toll roads is usually conducted through the use of transponders or automatic plate recognition. Both methods aim to eliminate the collections delays by debiting the accounts of registered vehicle owners without requiring them to stop. Given the technological requirements, open road tolling is more expensive.

- *Vignette:* A road tax vignette is a form of tax on vehicles. A small, colored toll sticker is affixed on a vehicle passing through motorways and expressways that indicates the road tax has been paid. Vignettes are valid for a fixed period of time, often one year but usually also available for less, and can be obtained at border crossings, gas stations and specifically labeled points. A vignette system is cheap to operate, as it does not need toll plazas or the infrastructure of a modern toll system. After the initial purchase, vignettes represent a sunk cost, so there is no disincentive to travel at a particular time or route, as cost is not based on distance travelled. It is less effective in limiting distance travelled when compared to tolls; and in that sense the value in terms of reducing GHG emissions is more limited.
- *Heavy-goods vehicle (HGV) tolling:* Given the higher environmental and road damage caused by heavy vehicles, a number of countries in Europe have introduced HGV tolling for trucks over 3.5 tons on trans-European journeys.
- *High-occupancy vehicle (HOV) lanes, high-occupancy toll (HOT) lane, express toll lanes (ETL):* Due to the high costs and impacts of creating new road capacity, increasing attention is being given to strategies that make the maximum use of existing highway capacity HOV, HOT, and ETL lanes that responds to a demand management approach. HOV lanes are designated for use only by vehicles containing multiple occupants. This creates an incentive for people to switch from driving alone to carpooling, thereby expanding road capacity. High-occupancy vehicles either without charge or with a reduced toll can use HOT lanes during peak hours. The toll is determined by hourly vehicle flows and is set high enough in peak hours to keep the number of users down and, consequently, speeds of vehicles on the road up. Vehicles carrying more than a specified number of passengers are permitted to use the HOV lanes at a reduced toll (hybrid lanes) or for free (HOT lanes). Express toll lanes (ETLs): the main difference between HOT and ETLs is that in HOT lanes, HOVs are granted free access, whereas in ETLs all vehicles pay according to the same schedule. Additionally, public transit vehicles are typically exempted from the toll. Creation of both HOV and HOT lanes is much more acceptable if it is done by adding capacity to an existing road, as the conversion of existing lanes reduces the overall capacity of the road, thereby increasing congestion on the remaining normal lanes. HOT, HOV, and ETL should be created only as part of the entire highway network in which they will be located, with full recognition of how those lanes will affect the whole network and impact on congestion in the network. Compared to general-purpose lanes, HOT, HOV, and ETL may provide environmental advantages by eliminating GHG emissions caused by stop- and-go traffic, and by encouraging people to use carpools and mass

transit, thereby reducing the number of vehicles on the road. Such lanes can only be implemented in high-density road corridors typical of larger metropolitan area with limited travel options and a lack of parallel highway routes.

- *Insurance per km of driving.* Insurance per km of driving or Pay As You Drive (PAYD) insurance directly incorporates distance travelled as a rate factor. Studies suggest that accident costs increase with annual vehicle kilometers driven and as a result, PAYD increases actuarial accuracy by rewarding motorists with reduced mileage. Critics argue that distance based insurance premium penalize non-urban vehicle use, who pay more because of lack of public transit. Studies show that in developed insurance markets, universal PAYD policies can reduce travel by 11.5%, while optional PAYD policies reduce travel by 3%.

Alternative fuels. Alternative transport fuels to petrol and diesel can reduce vehicle emissions as well as improving air quality and reducing reliance on imported fuel. Some well-known alternative fuels include biodiesel, bio-alcohol (methanol, ethanol, and butanol), chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas, biogas, vegetable oil, propane, and other biomass sources. These fuels may be used in a dedicated vehicle system that burns a single fuel, or in a mixed system with other fuels, including traditional gasoline or diesel, such as in hybrid-electric or flexible fuel vehicles.

- *Bio-fuels* are those fuels that are sourced from agricultural and forestry residues; and municipal wastes and are gaining increased public and scientific attention, driven by factors such as oil prices, the need for increased energy security, concern over GHG emissions from fossil fuels and government subsidies. The International Energy Agency estimates that by 2050 biofuels could provide 27% of total transport fuel and could replace diesel, kerosene and jet fuel.[3] An important factor when considering the GHG emission reduction potential of bio-fuels is their life-cycle impact.[4]
- *Natural gas*: A natural gas vehicle (NGV) uses compressed natural gas (CNG) or liquefied natural gas (LNG). Worldwide there are 12 million NGV vehicles, with the highest share in Armenia, where 30% of vehicles run on CNG due to fleet retrofits.[5] As with other alternative fuels, the use of NGV requires the development of fuel storage and infrastructure available at fueling stations. In the United States, CNG is popular with public transit agencies. NGV has a significant share of the

vehicle market, exceeding 10%, in Argentina, Bangladesh, Bolivia, Colombia, Iran and Pakistan. The US Environmental Protection Agency calculates the potential benefits of CNG versus gasoline for light-duty vehicles as reducing carbon monoxide emissions by 90-97%; CO_2 emissions by 25%, NO_X by 35-60%, potentially reducing non-methane hydrocarbon emissions by 50 -75%; and emitting little or no particulate matter. CNG reduces GHG emissions by 30% in vehicles and 23% in buses compared to gasoline and diesel. An additional option is renewable natural gas (RNG), also known as bio-methane, is the gaseous product of the decomposition of organic matter that has been processed to purity standards. Capturing biogas from landfills and livestock operations can reduce emissions by preventing methane release; reduce odors and produce nutrient-rich liquid fertilizer. For use as a fuel, RNG is chemically identical to conventional natural gas and can be compressed or liquefied for use in vehicles.

- *Hybrid electric and plug-in electric vehicles.* A hybrid electric vehicle combines a conventional (usually fossil fuel-powered) engine with some form of electric propulsion, while a plug-in electric vehicle (PEV) is a vehicle that can be recharged from any external source of electricity, such as wall sockets, and the electricity stored in the rechargeable battery packs drives or contributes to drive the wheels. When considering the GHG impact of PEVs it is important to keep in mind that if electricity production depends heavily on high- carbon energy resources then the net effect of PEVs will be modest.
- *Lower emission freight vehicles:* Freight vehicles are also a potential target group for use of alternative fuels to reduce GHG emissions. This sits within a range of measures that may (with Government encouragement) be taken by freight operators, including: vehicle aerodynamic modifications, use of alternative fuels, adoption of eco-driving practices, improved load consolidation/ organization to minimize vehicle-km and scrapping or replacement of older vehicles.

Voluntary measures. A variety of voluntary mechanisms can be established to encourage vehicle users and others in the road transport industry to reduce their carbon footprint.

- *Vehicle offset program.* This type of program typically provides a voluntary opportunity for road transport users to offset their vehicle emissions as part of the vehicle registration process. It is hoped that the offset program will counterbalance emissions from the transport sector in addition to raising consumer awareness of the environmental impact of vehicles.
- *Clean fleets.* In this type of program, business, non-for-profit organizations and government fleet vehicles join a program to reduce GHG emissions and other air pollutants. This type of program

seeks to assist organizations in reducing fleet emissions by providing information about low emissions fleet management practices and supporting conversion of vehicle procurement to clean and emerging technology fuel technologies.

- *Improving freight efficiency* is another important way to reduce travel demand. Higher capacity vehicles can reduce the total number of trucks on the roads and better scheduling of trucks reduces unproductive trips.
- *Material properties of paved surfaces*. There are tremendous emission reduction gains that can be made through use of new technologies for road surfacing, such as use of recycled materials. Changing the composition of the surface mix and raising its albedo an effective approach. While this increases solar reflectance, there are now pigments and coating structures that can be effective in both raising albedo and lowering reflectivity. Treatments of this type can lower pavement surface temperature and reduce per m^2 emissions (per 1% increment of albedo) by at least 2.5 kg/m^2.

The specific reactive strategies for road transport are:-

The development of the road network will be based on one integrated strategy covering all roads (except urban roads) from the federal highways to local community access roads.

The federal roads strategy involves the following six key activities:

- Alignment improvements to reduce travel times and enhance safety;
- Completion and upgrading of existing routes and undertaking new construction to connect new industrial growth centers;
- Construction of new alignments and diversions on key routes to reduce distances and allow increased speeds and/or driver comfort;
- Improvement of access routes between industrial centers and major border crossings;
- Introduction of improved engineering and construction technology to reduce overall life cycle costs and provide better service quality; and
- Establishment of a maintenance regimen for all federal and regional roads that includes pavement management systems and performance contracts.

Most of these activities already form part of the on-going roads strategy and are being implemented.

The regional network strategy covers all non-urban roads of a lower classification than federal road network and aims to provide sustainable and equitable access in rural areas, including remote communities, in consideration of available funding and an appropriate balance between the construction of new roads and the maintenance of existing roads. The critical activity at the planning stage is the creation of an agreed and coordinated regional transport (multimodal) master plan for each region that presents and prioritizes all transport investments, based on detailed inputs from the communities, regional and local governments while creating linkages to the federal transportation networks.

The completion and subsequent upgrading of roads to all regional centers is a priority. Following the completion of these roads, considerable pressure will remain to further expand the network to serve all significant population clusters. The regional road strategy entails:

- Development of a regional multi-modal transport plan in each region to provide the basis for planning, rationalization and prioritizing network development;
- Construction of feeder roads to all regional centers resulting in a comprehensive regional road network;
- Identification and prioritization of additional regional roads based on demand, population served and road length;

Review of construction standards and methods to ensure sustainability;

Progressive upgrading of all regional roads to all-weather (sealed) standards has to be prioritized based on traffic demand and construction of motor-able bridges to ensure all-weather accessibility; and Establishment of a program for routine and periodic maintenance activities.

Over the life of the Strategy, road transport should focus on expanding rural access to the road network, establishing multi-modal interchanges, and increasing the service level of roads and bridges through an improved maintenance schedule.
From a low-carbon perspective, non-urban road transport has the potential to provide the largest addition to emission reduction efforts with the introduction of advanced approaches to paving materials. These will supplement the fuel efficiency standards, introduction of bio-fuels and introduction of electric vehicles already underway.

An additional consideration is the introduction of low emission freight vehicles and the introduction of compressed natural gas (CNG) or liquefied natural gas (LNG) to power motorized vehicles. Both these options require a strategic decision.

3.1.1.2.4. Urban Transport

The physical layout and design of a city impacts daily travel patterns. The relationship between transport and urban form is mutually reinforcing, in the sense that transportation investment decisions influence spatial patterns of development, which in turn influence patterns of travel and these influence future transport investment decisions. Once a country has developed an urban form characterized by extensive urban sprawl, it becomes exceedingly difficult to control GHG emission growth. Strongly enforced land use policies, such as urban codes and land regulations, zoning for mixed use, density controls, eliminating minimum parking regulations (One of the biggest concerns with minimum parking regulations is that they waste a great deal of space by applying a "one size fits all" solution to a complex and evolving situation.), setting boundaries for urban growth, and spatial planning can make inroads into this relationship (relationship between transport and urban form). Transportation investments and policies can be used to support sprawl avoidance techniques:

Improving traffic flow: Transport systems can reduce emissions and ease congestion on key roads by installing technologies to coordinate traffic signals and on-ramps, vary speed limits, control lanes and monitor traffic flow. The systems can also collect traffic data, assist with future network planning and allow problem areas to be diagnosed more quickly allowing better responses to traffic incidents.

Urban congestion pricing is a system that charges users for use of a transport network, or portion of it, in order to reduce traffic congestion. It has been applied in a limited number of cities (London, Stockholm, Singapore, and Milan). The London Congestion Charge is a fee paid by drivers within the Congestion Charge Zone with the aim of reducing congestion, as well as raising investment funds for London’s transport system. Transport for London reports found that the charge reduced traffic by 21%. Congestion charging was also estimated to have led directly to a 16% reduction in GHG emissions from traffic.

Parking policy: One pricing mechanism to discourage vehicles use is the adoption of a policy of high parking pricing, particularly if parking is expensive in relation to mass transit public transport. Charging for parking is relatively widespread around the world. Generally, the amount of on-street parking is a function of municipal policy, while off-street parking is controlled by zoning and building regulations. Parking management options include: (a) High pricing; (b) Emissions based parking charges for different zones within the city (based on vehicle registration); (c) Supply caps on the number of parking spaces available; (d) Regulating the location of parking; and (e) Earmarking parking fee revenues for non-vehicle transport development.

Park and ride facilities: A complementary approach is the development of park and ride facilities at the end of transit lines to increase public transit usage and reduce the number of vehicles driving through the city center.

Switching transport modes for reduced dependence on vehicles can be achieved in a number of ways, including, intermodal transport efficiencies, transit-oriented design, investing in alternative transport infrastructure for bicycles and pedestrians, bicycle use promotion and raising awareness about the benefits of using alternative modes.

Transit-oriented development *(TOD)* is a development that includes a mixture of housing, office, retail and/or other amenities integrated into high-density residential neighborhoods and located within a half-km of a public transport node. Some of the benefits of TODs include:

- reduced household driving and thus, lower congestion and air pollution (GHG emissions),
- walk-able communities that accommodate healthy and active lifestyles,
- increased transit ridership and fare revenue, potential for added value through increased and/or sustained property values where transit investments,
- improved access to jobs and economic opportunities for low-income people and
- Expanded mobility choices that reduce dependence on the vehicles.

The specific reactive strategies for urban transport are:-

Ethiopia's cities require integrated transport plans to address the needs of their expanding populations and city areas. The growth in population and the increasing challenge of mobility and motorized vehicles will result in serious traffic congestion unless action is taken.

The urban transport strategy should focus on providing attractive public transport services and facilities for pedestrians, so that walking becomes the dominant mode in the central business area and for short trips. The strategy must also seek to control the impact of private vehicles through careful management of vehicle numbers and use. The overall objective is to create vibrant, functional, and livable "green" cities, thus minimizing the adverse effects of traffic growth.

While the responsibility for implementing and realizing urban strategies lies principally with the municipality as coordinator and provider of urban services, urban sustainability and mobility strategies should call for, at a minimum, the following key activities:

- Review and updating of the existing plans based on the revised population and vehicle ownership forecasts, including the preparation of an urban transport plan;
- Improvement to traffic engineering and management system, including better use of existing road space, provision of safety enhancements and revision of traffic circulation;
  - Development of public transport, including identifying measures to boost ridership, both short- and long term; and
  - Improvement of facilities for pedestrians, including a safe and secure network of routes and priorities within the central area.
  - Review the existing urban road planning tradition to give more focus and attention to pedestrians, cyclists and public mass transport systems where the majority of urban population depends on.
  - Retrofit with new design the urban road network and facilities to enhance walking, cycling and mass transportation systems.

3.1.2. Assessment of feasibility of mitigation options in Ethiopian context

In identifying suitable mechanisms for GHG mitigation, the most important aspect to consider is that until infrastructure and regulatory changes are in place and have been enacted, major changes are not likely.

Following an in-depth review of known implementation practices for the noted mitigation options, the most promising mechanisms not included in the CRGE were reviewed for suitability in an Ethiopian context. The preferred options have the following features:

- Easy, quick, inexpensive and cost-effective to implement;
- Able to successfully assess impacts (and separate technical information from value judgments);
- Capitalize on existing infrastructure, skills and resources
- Facilitate selection of a variety of management actions; and
- Produce defensible decisions;

The selected mechanisms were considered because of feasibility of implementation and proven success elsewhere. The mechanisms were then prioritized for high potential for GHG mitigation and high feasibility of implementation in the short- and medium-term. A number of critical success factors are taken into account such as the complexity and technical capacity that needs to be in place, the cost of implementation in comparison with the benefits, and the political support that will be demanded in order to ensure an enabling institutional and legal environment to realize these opportunities.

Table 12: Assessment of feasibility of selected mitigation options

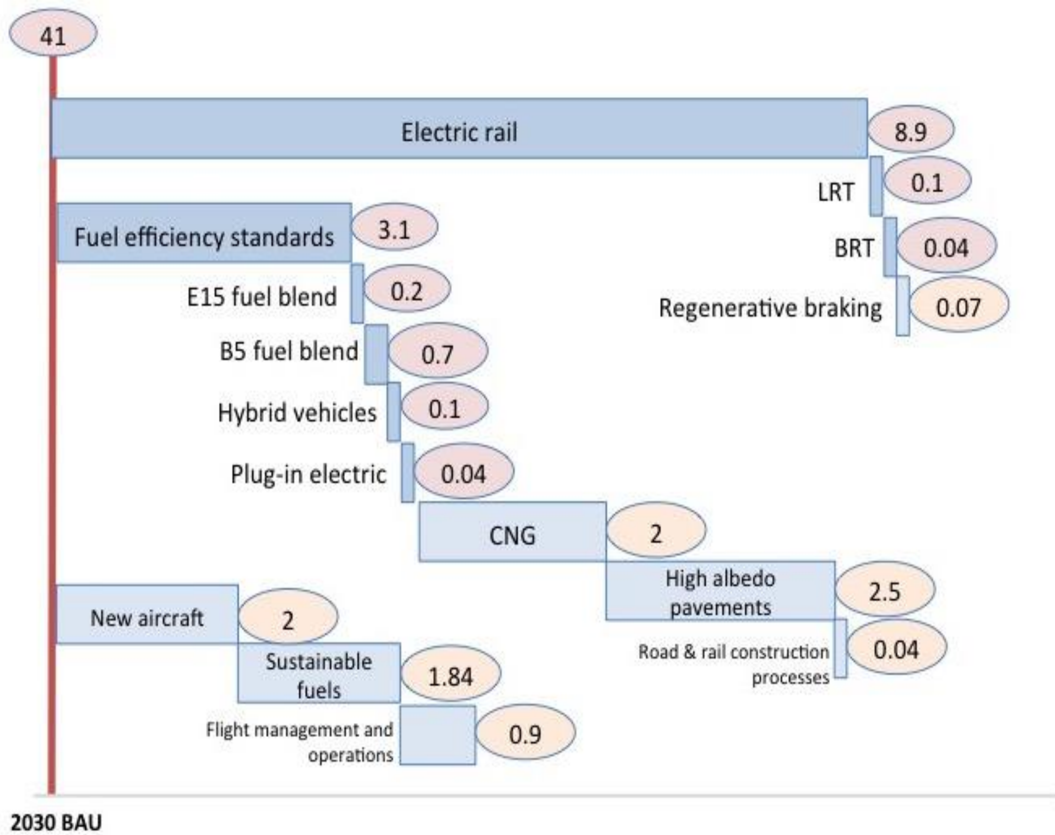
Measure	Time to Implementation	Implementation Cost	Barriers to Implementation		Benefits
			Institutional	**Operational**	
Air Transport					
Emission capping	Medium – Long Term	Medium	High	Medium	High
Emissions trading	Medium – Long Term	Medium – High	High	High	Low – Medium
Jet fuel taxation	Long term	High	High	High	Medium
Surface emissions, terminal and technical support facilities	Short – Medium Term	Low – Medium	Medium	Low	Medium
Improved air traffic management	Short – Medium Term	Low – Medium	Low – Medium	Low	Medium – High
Improved airplane, and airport operating procedures	Short – Medium Term	Low – Medium	Low – Medium	Medium	Medium – High
Rail Transport					
Improving aerodynamics & reduction of train weight	Short – Medium Term	Low – Medium	Low	Low – Medium	Low – Medium
Regenerative braking	Short Term	Low – Medium	Low	Low – Medium	Medium – High
On-board energy storage	Short – Medium Term	Low – Medium	Low	Low – Medium	Medium

Measure	Time to Implementation	Implementation Cost	Barriers to Implementation		Benefits
			Institutional	**Operational**	
Energy efficient driving and efficient matching of rail stock	Short – Medium Term	Low – Medium	Low	Low – Medium	Medium
Road Transport					
Vehicle registration tax	Short – Medium Term	Low – Medium	Low	Low	Low
Toll road pricing	Medium – Long Term	Medium	Medium	Medium	Low
Road tax vignette	Short Term	Low – Medium	Low	Medium	Low
Natural gas (conversion)	Short Term	Low	Low	Low – Medium	High
Natural gas (system)	Medium Term	Low – Medium	Low	Low – Medium	High
Lower emission freight vehicles	Medium Term	Medium – High	Low	Low – Medium	Medium – High
Clean fleets	Medium Term	Medium – High	Low	High	Medium – High
Improving freight efficiency	Short – Medium Term	Low	Low	Low – Medium	Medium – High
Material properties of paved surfaces	Short – Medium Term	Medium	Low	Low – Medium	High
Urban Transport					
Improving traffic flow	Medium Term	Medium – High	Low	High	Medium – High
Parking policy	Medium Term	High	Low	Low – Medium	Medium

Measure	Time to Implementation	Implementation Cost	Barriers to Implementation		Benefits
			Institutional	**Operational**	
Transit-oriented development	Medium – Long Term	High	Low	High	Medium – High

The CRGE already includes some of the major mitigation options typically recommended for inclusion in a GHG abatement program. In many of the cases, implementation on these has already started. Thus, any additional proposed GHG abatement measures will add flexibility to Ethiopia's approach to achieving a low carbon economy.

FIGURE 13: TRANSPORT ABATEMENT POTENTIAL OF CRGE AND SELECTED MITIGATION OPTIONS



Legend: ● / ● CRGE options/abatement potential; ● / ● selected mitigation options/abatement potential
Source: Abatement estimates for the selected mitigation options derived from comparable best practice experience in other countries and related calculations

3.1.3. Adaptation (Resilience) opportunities for reducing vulnerability to climate change risks

3.1.3.1. An adaptive and reactive strategy of climate resilient infrastructure

Building transport infrastructure resilient to future climate change is an important component of green growth strategy. Climate resilient infrastructure reduces the likelihood of shocks to the economy and society, which happen due to extreme weather conditions. Having such infrastructure that can overcome the challenges of weather shocks will induce lower costs of the after-shocks recovery and be able to implement actions needed for the recovery in a timely fashion. Such an action helps to sustain economic and human outcomes (reduced death and injury expenses) that are likely to happen after shocks. The importance of weather resilient and high quality infrastructure makes it one of the main indicators of a country`s sensitive to climate change. Thus, climate change projections are critically important in planning transport infrastructure investment and maintenance. Therefore, two major alternative approaches proposed as an important strategic option to overcome the impacts of future climate change. The two strategies are adaptive and reactive strategies.

Adaptive strategy: Refers to building more resilient transport infrastructure with new design standards in anticipation of climate change based on projected climate scenarios. Such a strategy involves high up-front investment balanced by lower costs during the lifetime (life span) of the asset.
The identification of a robust adaptation strategy relies on a systematic evaluation of all possible combinations of planning scenarios, planning horizons and climate outcomes. It is also important to indicate clearly adaptation cost matrix across a range of climate scenarios covering the entire range of the adaptation cost.

Reactive strategy: It advocates maintaining the already existing design standards and managing the impacts of climate change once it happened. As opposed to adaptive strategy reactive strategy option involves a risk of costly replacement of the infrastructure before the end of its economic life.
In general, the choice between the two strategies should take into account the presence of a wide range of projection of the future climate change and a long life of the infrastructure assets. Moreover, the priorities for adaptation strategy have better work for physical infrastructures like urban drainage systems, health, education and municipal buildings. Thus, the design for such infrastructure assets can

adopt new design standards, operations and maintenance practices in a cost effective manner based on climate projection scenarios. However, reactive strategy best fits for road infrastructure in such a way to help to plan enhanced maintenance and upgrades to respond to weather stresses. The main factors of the costs in both strategies are the impact of climate events on the infrastructure, the planning horizon (how far ahead), and the nature of climate uncertainty.

Cognizant to this, the infrastructures should be built differently to be resilient to climate change. Projected changes in climate patterns will affect the reliability and quality of infrastructure services. Temperature increase will cause roads to degrade, and intense rainfall events will leads to drainage system to overflow.

Adaptation consists of actions responding to climate change impacts and vulnerabilities, and is therefore focused on protecting infrastructure and services against negative impacts, but also on building resilience by taking advantage of any possible benefits from these changes. The uncertainties inherent in projecting long-term climate changes – coupled with the long service life of most transportation infrastructure present a complex challenge for transportation decision-making.
Because today's transportation network likely will be in place for decades to come, investment and design decisions made today need to consider potential changes in climate conditions in the future: 30, 50, and sometimes 100 years or more from now.

The following is a brief overview of the types of measures that are currently considered as best practice in adaptation to climate proof transport infrastructure. This review does not attempt to present a list of potential adaptation measures for each transport sub-sector, but rather a broad categorization of policy options, keeping in mind the need for additional knowledge to bridge identified gaps. Building the information base on vulnerabilities is a key to adopt concrete measures on the ground, and international activity to date has focused primarily on building adaptive capacity, rather than adapting to specific future projections of climate. Key focus areas have included research to understand current and future vulnerability; development of guidance and tools; identification of adaptation measures; review of standards; adoption of resilience measures actions including weather prediction, monitoring and contingency planning; and scheduling adaptation to time with asset renewal.

Developing an effective adaptation program depends on a robust understanding of vulnerability to current and future climate and the risk that these changes pose. Vulnerability is a function of a system's exposure and sensitivity to the impacts of climate change and its capacity to adapt.[6] The aim of a vulnerability assessment is to highlight the relative vulnerability of assets or services to the impacts of climate change. Understanding vulnerability is a key to developing adaptation plans that minimize risk and maximize the opportunities associated with the impacts of climate change. A climate change vulnerability assessment should be focused on those issues and assets that have been determined to be sensitive to weather and climate variables in order to effectively guide prioritization and decision-making. Depending on the nature and scale of the assessment and the availability of data, the anticipated magnitude of the costs can be expressed quantitatively or qualitatively.

A vulnerability assessment can be carried out at a range of scales, from individual assets or services to complex systems. The chosen level of scale may also relate to the assets or services in question; for example in areas of heterogeneous climate, exposure may be very different even if sensitivity or adaptive capacity is similar. Vulnerability assessments are often the first step to determining the climate proofing needs of a system. Among the activities likely to be identified as adaptation interventions by a vulnerability assessment are: (a) Review of design and safety standards; (b) Incorporation of adaptation considerations into infrastructure asset management systems; (d) Emergency preparedness planning; and (e) Revised planning and project development documentation.

Review of design and safety standards: Effort must be made to review and update, where necessary, infrastructure design standards to ensure that future investments in infrastructure are more resilient to anticipated climate change. The evidence suggests that this is likely to be most cost effective for assets with a long life, such as bridges and ports. There is a clear need for a similar kind of assessment to be conducted in Ethiopia across all transport modes.

Incorporation of adaptation/resilience (reactive) considerations into infrastructure asset management systems:

[6]**Sensitivity** refers to the degree to which the system is affected by weather or climate variables, or the change in those variables. **Exposure** refers to the extent to which the system is subject to weather or climate variables. **Adaptive capacity** refers to the ability of a system to adjust to climate driven changes, to moderate potential damage or to take advantage of opportunities

An asset management system can be used as a decision-making framework for incorporating adaptation concerns into a management approach. Given that most transportation agencies already have some form of asset management systems, it is a convenient and targeted approach to incorporate climate-induced change into transportation decision making. Asset management relies on monitoring the performance of systems and analyzing the discounted costs of different investment and maintenance strategies.

For existing infrastructure, the key issue is making efficient choices about maintenance and replacement. In constructing new infrastructure, asset management involves evaluating total life-cycle costs — both the initial capital costs and the subsequent costs for operation, maintenance, and disposal — to ensure that not only are projects prioritized appropriately, but also that they are built cost effectively. There are a number of ways in which climate change monitoring techniques or adaptation strategies could be factored into an asset management system.

TABLE 13: CLIMATE RESILIENT ASSET MANAGEMENT SYSTEM

Asset Management System Component	Monitoring Technique / Adaptation /resilience/ Strategy
Goals and policies	Incorporate climate change considerations into asset management goals and policies; these could be general statements concerning adequate attention of potential issues or targeted statements at specific types of vulnerabilities
Asset inventory	• Mapping of infrastructure assets in vulnerable areas; • Inventory critical assets that are susceptible to climate change impacts
Condition assessment and performance modeling	• Monitor asset condition in conjunction with environmental conditions (e.g., temperature, precipitation) to determine if climate change affects performance, and incorporate risk appraisal into performance modeling and assessment; • Identify high risk areas and highly vulnerable assets; • Use of smart technologies to monitor the health of infrastructure asset
Alternatives evaluation and program optimization	Include alternatives that use probabilistic design procedures to account for the uncertainties of climate change. Possible application of climate change-related evaluation criteria, smart materials, mitigation strategies and hazard avoidance approaches.

Asset Management System Component	Monitoring Technique / Adaptation /resilience/ Strategy
Short- and long-range plans	• Incorporate climate change considerations into activities outlined in short- and long-range plans; • Incorporate climate change into design guidelines; (adaptive) • Establish appropriate mitigation strategies and agency responsibilities.
Program implementation	• Include appropriate climate change strategies into program implementation; • Determine if agency is actually achieving its climate change adaptation/ monitoring goals
Performance monitoring	• Monitor asset management system to ensure that it is responding effectively to climate change; • Possible use of climate change-related performance measures; • "Triggering" measures used to identify when an asset or asset category have reached some critical level.

Source: Meyer, M.D. *et.al.* (2009)[7]

Emergency preparedness planning: A number of actions can be done to prepare for emergencies. Early warning weather information systems can be used in order to improve response to extreme weather events. These systems provide on demand weather forecasts by special infrastructure weather models for weather warning system, flash flood warning system and fire risk warning system. They lead to better prevention of adverse impacts related to natural disasters and have significant cost reduction potential. A second policy is to develop contingency management and planning of service delivery, when disruptions occur due to weather related events is an important measure for ensuring resilience of infrastructure and transport services. The aim is to ensure that the transport industry is effectively prepared for, and able to respond to and recover from, emergencies such as those resulting from extreme weather events.

Revised planning and project development documentation: Climate adaptation can be addressed in the transportation planning; and project screening and development processes by:

(a) Making changes to support longer planning timeframes;

(b) Providing guidance on the incorporation of quantitative and qualitative climate considerations; and how to address uncertainty;

(c) Requiring climate change adaptation screening in ESIAs by reviewing and updating regulations and procedures where climate impacts and adaptation are relevant; and
(d) Requiring inclusion of adaptation considerations in project tender documentation.

Adaptation can be integrated in the project development cycle by focusing on:

(a) Identifying the climate sensitivity of the project;
(b) Evaluating exposure to climate hazards;
(c) Assessing vulnerability;
(d) Assessing risk;
(e) Identifying adaptation options;
(f) Appraising decision makers of adaptation options; and
(g) Integrating adaptation action plans into the project development cycle.

In addition, the planning process should require the maintenance of nationally standardized data sources and modeling techniques for transportation climate adaptation planning and for input to project development.

Effective adaptation requires an ongoing, iterative process of risk and vulnerability assessment, adaptation action, performance assessment, monitoring, and continuing adaptation, institutional collaboration to bring together the scientific, engineering, and planning resources necessary to make good decisions. Climate impacts assessment and adaptation planning is not a stand-alone process. In order for climate impacts assessment and adaptation to be pursued effectively, they must be integrated into the ongoing transportation decision-making process.

3.1.3.2. Recommendation for adaptation measures

The following are recommendations on adaptation/resilience measures aimed at reducing the risk of the negative effects of climate change: Adaptation (as defined by McKeown and Gardner) includes changes in policies and practices designed to deal with climate threats and risks.

Adaptation can refer to changes that protect livelihoods, prevent loss of lives, or protect economic assets and the environment. In the context of transportation, adaptation can be thought of as the transportation sector's response to the climate impacts discussed above: what can or should be done to help the transportation system respond to the changing climate?

A range of adaptation and resiliency strategies are necessary to address the various climate change impacts to the transportation system discussed in the preceding section.

For all transport modes:

- National study of vulnerability by sector and mode that would involve conducting a comprehensive and detailed risk assessment. Outputs include a mapping of risks, as well as an action plan for short-term, medium-term, and long-term;
- Revised planning and project development documentation. Require climate adaptation to be addressed in the transportation planning and project development processes, by:
    a. Making changes supporting longer planning timeframes;
    b. Providing guidance on the incorporation of quantitative and qualitative climate considerations and how to address uncertainty;
    c. Require climate change adaptation screening in ESIAs by reviewing and updating regulations and procedures where climate impacts and adaptation are relevant; and
    d. Require inclusion of adaptation considerations in project tender documentation. In addition, the planning process should require the maintenance of nationally standardized data sources and modeling techniques for transportation climate adaptation planning and for input to project development;

- Review of design standards for each transport mode to factor in expected climatic risks that emerge from the vulnerability assessment and the mapping of risks;
- Development of Emergency Preparedness Planning for each transport entity and sub-sector, in line with projected climatic impacts; and
- Inclusion of projected future climate impacts into infrastructure asset management systems. Given that all transportation entities have some form of an asset management system, it is a convenient and targeted approach to incorporate climate-induced change into transportation decision-making, including project selection and implementation.

Airports:

- Studies are required for vulnerability of airport infrastructure and systems to a changed (changing) climate conditions, for all Ethiopian airports. A comprehensive and detailed risk assessment should be undertaken, using the best available climate change forecasts and use of rainfall-runoff and hydraulic models. This should include consideration of the effects of prolonged periods of high temperatures and increased potential flood frequency due to increased rainfall intensity. Airport-specific adaptation plans (including actions, timescales and budgets) should be drawn up, including prioritization based on the risk assessment. This should form the basis of future adaptation actions; and
- Implementation of heat and flood resilience infrastructure measures: Within the design and implementation of all new airport infrastructure and in any refurbishment or upgrading, measures should be included to take account of the likelihood of changes in temperatures and more frequent extreme weather events. This could include, for example, use of revised pavement material specifications for runways, taxiways and aprons and greater drainage capacity and flood protection.

Rail:

- Implementation of heat and flood resilience infrastructure measures: Within the design and implementation of all new track infrastructure (permanent way) projects and in any refurbishment or upgrading, measures should be included to take account of the likelihood of increased flooding and high temperatures.

  This could include, for example, consideration of bridge expansion joint design, improved maintenance of existing tracks, better management of trackside vegetation and greater drainage capacity and flood protection; and
- Develop long-term plan to gradually introduce improved ventilation and/or air conditioning in rail rolling stock in order to allow passengers to travel in reasonable comfort during high temperature periods.

Road:

Operational. In the short term, changes in operations and maintenance practices due to changes in the climate and climate extremes are necessary and already are happening in some areas. These responses include incorporating extreme weather events into routine operations, improving collaboration with weather and emergency management as part of agency operations, and sharing best practices. Maintenance and asset management practices may need to be updated to accommodate changes in environmental factors.

Design. Design changes to new infrastructure to address future climate conditions will mitigate some expected impacts. In the medium term, changes in design and materials (revision of design standards to address climate change impacts, or rehabilitation to meet revised standards) can protect infrastructure from climate changes. In addition, monitoring and use of sensor technology can provide advance warning of potential infrastructure failures due to the effects of weather and climate extremes on transportation systems.

Design standards. Development of new design standards also is identified as a need to incorporate the impacts of climate change into design and operations. This includes both infrastructure design standards as well as revision of flood frequency standards to reflect climate projections rather than only historic trend data (e.g., the 100-year flood may now be a 25-year flood). Along with new design standards there is a need to develop ways to share best practices for adaptation design strategies which state and local governments can easily access.

Land Use. Long-term adaptation strategies might include changes in land use management policies in order to reduce risks to people and transportation infrastructure by avoiding areas vulnerable to climate change. Changing conditions may necessitate the relocation of existing infrastructure. Land use also may be utilized to realize the potential of natural systems (such as wetland buffers) to reduce risk to both infrastructure and communities.

The range of adaptation strategies can be divided into four categories of options:

1. Manage/Maintain. These strategies assume that an increasing cost to repair and maintain infrastructure will be experienced due to increasing stress from severe events. A shorter service life also is possible due to increased climate stress. An incremental approach of absorbing increased damage into annual maintenance cycles may be a reasonable and cost-effective strategy for infrastructure that is at lower risk or is less significant to overall mobility goals.

2. Protect/Harden. These strategies enhance the resilience of infrastructure through techniques such as changing design standards (e.g., higher bridge heights, elevated roadways), building engineered protection (e.g., levees), developing or enhancing natural buffers (e.g., wetlands), etc. Essentially, this approach tries to ensure that existing and future infrastructure withstands projected changes in climate. It is most appropriate for critical infrastructure that is at risk and needs to stay in operation.

3. Develop Redundant Services. These strategies prepare for intermittent loss of service by developing alternate routes or services to maintain continuity of travel when service is disrupted.

Yet it is also essential that the forthcoming investment in the Ethiopian roads take into account the very real risk of climate change. Roads are particularly vulnerable to climate stressors such as increased temperature and precipitation and flooding. For paved roads, increased temperature leads to accelerated aging of the pavement binder and rutting of asphalt. For paved and gravel roads, increased precipitation and flooding lead to reduced load-carrying capacity and overtopping of roads, among other impacts.

The effects of climate stressors on road infrastructure, which include both increased maintenance and a potentially shorter useful life between rehabilitation cycles, also give rise to indirect effects, such as disruption of unimpeded travel of people and goods, either because the road surface is damaged or destroyed, or because it is in the process of being repaired. These disruptions in turn affect economic activity and productivity.

Fortunately, there are effective ways of adapting new roads and modifying existing roads to make them more resilient to climate change. The challenge is in determining the most cost-effective and appropriate adaptation pathway given the high degree of uncertainty in climate projections.

- A comprehensive and detailed risk assessment should be undertaken, using the best available climate change forecasts and use of rainfall-runoff and hydraulic models. This should include consideration of the effects of prolonged periods of high temperatures and increased potential flood frequency due to increased rainfall intensity. RRAs should be consulted with respect to cross-region measures. A network-wide (federal and regional) adaptation resilience plan (including actions, timescales and budgets) should be drawn up, including prioritization based on the risk assessment. This should form the basis of future adaptation resilience actions;
- Review of design standards to factor in expected climatic risks for increased precipitation and temperatures: (a) reassess parameters used for design storm/flood for drainage systems and structures; (b) investigate the need for river training and increased channel maintenance and bridge scour protection; (c) review culvert designs to ensure they cause limited damage to roads during flooding; (d) reassess methods for slope stabilization and protection; (e) bridge expansion joint design; and (f) prepare new pavement specifications;
- Development of a long-term plan to upgrade and replace bridge infrastructure;

- Review of road asset management system to incorporate adaptation considerations during the planning of investments and operations and maintenance of roads; and
- Implementation of resilience infrastructure measures (design and/or material specifications) to address higher service temperatures and increased precipitation and flooding. Within the design and implementation of all new road infrastructure, and in any refurbishment or upgrading, measures should be included to take account of the likelihood of increased temperatures. Including for new infrastructure, measures should be designed in that provide greater drainage capacity and flood protection, retro-fit flood protection measures on existing infrastructure and reinforcement of bridge sub-structures.

Urban Transport:

- In addition to the plans already underway, plan for increased maintenance costs due to heat and possible damage from flooding; and
- Develop long-term plan to gradually introduce improved ventilation and/or air conditioning in public transport vehicles and rail rolling stock in order to allow passengers to travel in reasonable comfort during high temperature periods.

3.2. Increased Coordination Capacity at Ministry of Transport

At a national level, the legal, institutional and policy framework for all modes of transport is under the jurisdiction of the MoT. The CRGE Strategy drives the development of a new, climate resilient approach to managing and responding to climate change in the transport sector, by setting ambitious, legally binding targets and enhancing Ethiopia's ability to adapt to the impact of climate change. The GoE is in the process of establishing clear and regular accountability within the sector regarding climate adaptation and mitigation.

To support the sectors' need to develop an approach to integrating different aspects of the sector into a cohesive whole and support the transition from traditional single mode planning to multi-mode and accessibility planning, there is a need to increase the MoT coordination and oversight capacity. The institutional framework of and the capacity of the staff at MoT are at an unacceptably low level. Certain critical planning and coordination functions cannot be undertaken and some regulatory oversight functions are sorely inadequate. This raises the risk profile of sector as it starts to proactively address climate change risk and reduce sectoral vulnerabilities.

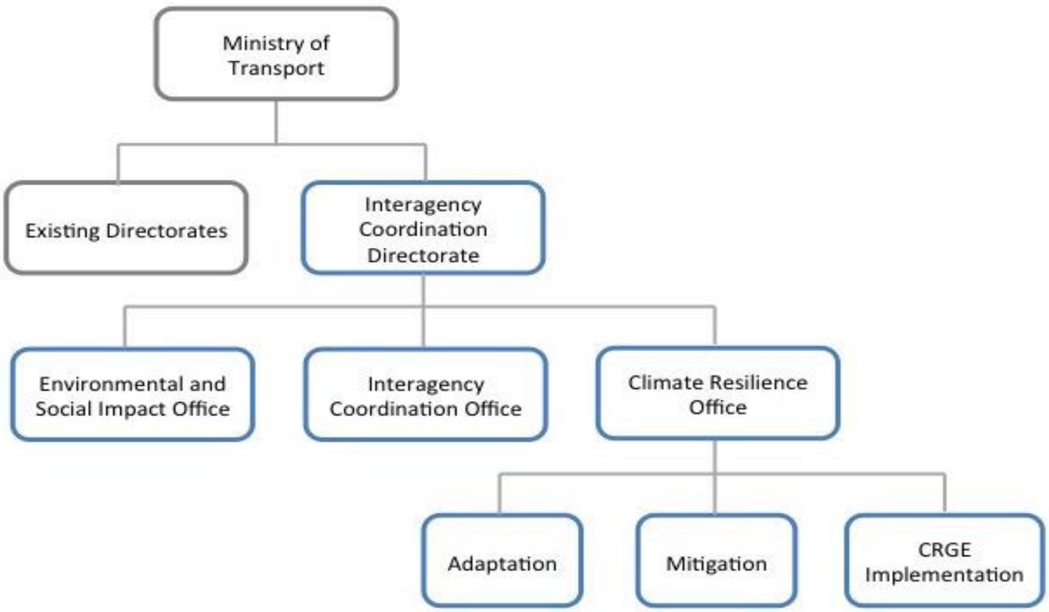
Planning and Institutional Changes. Institutional changes to integrate consideration of climate impacts into the transportation planning and investment decision-making process, along with more comprehensively incorporating other planning processes (e.g., economic development and ecological systems), will result in more resilient and cost-effective transportation systems. Possible changes that could be made include:

Lengthening the planning horizon of the transportation system past its current twenty- to thirty-year outlook, introducing risk assessment and vulnerability analyses, incorporating climate change into considerations, and forming new institutional arrangements and partnerships.
In the short run, these changes may be driven by immediate local concerns about specific climate factors. In the longer term, a systematic approach is required to incorporate a range of climate information into transportation decisions.

The adaptation responses can be thought of as lying on a continuum of planning and investment choices. Each requires different management actions and provides different benefits and costs to the agency.

A key recommendation for addressing this gap is the establishment of an *Interagency Coordination Directorate* in the MoT that will be oriented and have input towards achieving the nation's policy objectives in regard to climate resilience and environmental management.

FIGURE 14: *ADDITIONS TO THE INSTITUTIONAL STRUCTURE TO SUPPORT IMPROVED COORDINATION*



Within this directorate, the *Climate Resilience*, the *Environmental and Social Impact Assessment* and the *Interagency Coordination Offices* will ensure that environmental, social and climate resilience management frameworks are properly integrated into the sectors' management and project approaches and that interagency planning and policy coordination and concurrency are improved to ensure a successful transition to multi-mode and responsive transportation planning.

3.3. Implementation

To deliver the Strategy, implementation plans will be developed. The MoT will work with the regional and local governments and other sector partners to develop practical and effective actions that will then be integrated into the GTP.

3.3.1. Priority Actions for Implementation of the Strategy

The following are the priority actions for implementation in the immediate short-term (1–2 years). These actions are considered to be of outmost importance to the establishment of a sustainable and climate resilient long-term approach to implementation of the entire Strategy and will serve as the foundation upon which the sustainable transport and mobility can be achieved in Ethiopia.

TABLE 14*: PRIORITY ACTIONS FOR IMPLEMENTATION*

Priority Action	Lead Responsibility
Clarification and streamlining of mandates and responsibilities for all the transport sector entities	MoT
Establishment of a well-capacitated interagency coordination directorate	MoT
Review of design and safety standards to ensure that infrastructure is more resilient to anticipated climate change and that service levels remain high throughout the life of the asset	ERA, ERC and EAE for their respective sub-sectors
Undertake evidence-based sectoral vulnerability assessment to determine climate-proofing needs	MoT
Establishment of sectoral asset management database that includes evidence based climate risk aspects for all level of infrastructure assets and all sub-sectors	MoT in coordination with ERA, ERC and EAE
Update existing sub-sectoral strategies (road, air, rail, rural access, corridor strategies) that address the objectives of sector Strategy and incorporate identified vulnerabilities and risk	ERA, ERC, EAE and MoT for their respective sub-sectors
Develop sub-sectoral strategies (interchange strategy, modal delivery plans, urban transport plans and freight strategy) that address the objectives of sector Strategy and incorporate identified vulnerabilities and risk	Respective mandated agencies with coordination and leadership from MoT
Develop regional transport strategies that address the objectives of sector Strategy and incorporate identified vulnerabilities and risk.	RTAs with guidance from MoT
Develop risk reducing maintenance programs.	ERA, ERC and EAE for their respective sub-sectors and Addis Ababa Urban Transport Authority

Priority Action	Lead Responsibility
Develop disaster management and post-disaster recovery plans developed	ERA, ERC and EAE for their respective sub-sectors and Addis Ababa Urban Transport Authority
Develop service level guidelines for rapid transit network	Addis Ababa Urban Transport Authority with support from MoT and ERC
Travel information and ease of use of public transport system are improved (initial focus on Addis Ababa and its immediate environs)	FTA and Addis Ababa Urban Transport Authority with support from MoT
Revised planning and project development documentation to include climate change, environmental and social impacts	ERA, ERC and EAE for their respective sub-sectors
Establish GHG emission capping programs as part of the update to the sub-sector strategy and work plans, including in surface emissions, terminal and technical support facilities and infrastructure as well as related operational measures	EAE, Ethiopian Airlines and CAA
Establish targets for technical and operational performance improvements to support increased GHG emission reductions such as energy efficient driving, regenerative braking and efficient matching of rail stock to demand as part of the update to the sub-sector strategy and work plans	ERC and Addis Ababa Urban Transport Authority
Establish testing and maintenance protocol to support GHG emissions reductions through material properties of paved surfaces, specifically surface mix and raising of albedo	ERA
Improved transport system safety	MoT with support from all agencies and institutions
Initiate discussion and review of potential for introducing CNG and LNG to the vehicle fuel mix	MoT

CHAPTER FOUR

CONCLUSION

This strategy has presented the results of the rapid assessment of the transport sector, focusing on current conditions, climate risks, potential and opportunities for mitigation and adaptation. Based on these, the overall conclusion is that there is significant potential for climate change mitigation to address the growth of transport sector GHG emissions in Ethiopia. The recommended actions complement and reinforce transport measures that have already been proposed in the CRGE and that may also be under consideration for other reasons — economic development, efficiency, connectivity, environmental safety and security — with co-benefits in the form of GHG reductions. Within the recommended actions, climate change benefits, and indeed economic and other benefits, will only be realized if all aspects of transport service provision are addressed holistically. This would require not only infrastructure investments, but also interventions aimed at improving: (a) The operation of transport services; and (b) Efficiency in the management and organization of systems. This is particularly relevant to the rail sub-sector, freight service provision and urban public transport services.

With respect to adaptation and creation of system resilience the conclusion is that, in the period from the present to 2050, climate change could cause to all transport infrastructures:

• **Direct damages**: tens of billions of dollars in damages to roads, which will require additional maintenance to preserve basic serviceability; preliminary estimation of damage to bridges suggests costs may be even higher.

• **Substantial system disruption**: apart from increasing maintenance costs, climate changes will cause the disruption of road links, interrupting the flow of goods and people, all of which has a substantial economic cost.

While road and bridge infrastructure is a critical element in the development of economies in Ethiopia, there would be more economic burden to fund and execute the maintenance of road and bridge networks. One implication of strategy is that the prospect of climate change will increase the need for maintenance and rehabilitation for all types of roads and bridges, in virtually all climate contexts, putting continued pressure on an already stressed system.

A first key area of focus for transport sector authorities is therefore to incorporate climate change in road asset management, with a particular focus on institutionalizing regular road maintenance.

Funding and adequately executing the regular functions of maintenance is a first key step towards increasing the climate resilience of roads and bridge assets. Ethiopia needs therefore to promote a range of initiatives in this area, including a note on how to integrate climate change in road asset management. These efforts will help inform a consistent approach to planning for climate resiliency across countries.

This strategy also points to a second area of recommendations, concerning engineering design solutions as effective options to address the impacts of climate change. These solutions can provide long-term resilience, with less disruption and lower lifetime maintenance costs, in exchange for a higher up-front investment. In particular investing proactively in pavement improvements to withstand increased temperature is economically justified under most climate projections, even without taking into account the cost of increased disruption time.

Proactive adaptation to precipitation and flooding events is more expensive, and is unlikely to be justified in the shorter term solely on the grounds of reducing the lifetime expenditure on road assets (the sum total of construction, maintenance and rehabilitation costs). For damage caused by these climate stressors, it is important to consider not just financial costs but disruption of traffic volume and critical economic links.

For all modes of transport, as more severe precipitation and flooding changes will manifest themselves repetitively, and as the costs and risks of inaction grow larger over time, indications are the case for adaptation (based on both the financial and the avoided disruption time) will grow stronger as well. In the shorter term, it is important to avoid blanket prescriptions for infrastructure adaptations, opting instead for specific interventions on resilient design, according to the circumstances of each project and individual economic analyses.

APPENDIXES

APPENDIX A – THE PRINCIPLES UNDERPINNING THE VISION FOR THE TRANSPORT SYSTEM

The key principles underpinning the vision are consistent with the Government's vision outlined in the CRGE and the GTP:

INTEGRATED

- Recognizes the need for end-to-end solutions for people and freight; has effective links within and between modes, with each playing its appropriate part, for increased efficiency and effectiveness;
- Complements and does not compromise decisions or interests in other sectors;
- Considers funding throughout planning processes; and
- Ensures that transport interests are incorporated into, and contribute to, broader spatial planning initiatives.

RESPONSIVE

- Recognizes that people and freight need to move at different times and use different transport modes;
- Recognizes the direct effect transport has on people and their quality of life, and takes into consideration the diverse characteristics of communities and regions across the country;
- Has the flexibility to react to economic, social, environmental and technological changes; and
- Is prepared for, and recovers well from, unforeseen events.

SAFE

- Meets expectations for levels of acceptable risk;
- Protects key transport routes and services (in the event of natural or other disasters);
- Values the health and safety of all transport users, workers and operators equally; and
- Is based on design, operating and maintenance standards that protect life, property and nature;

AFFORDABLE

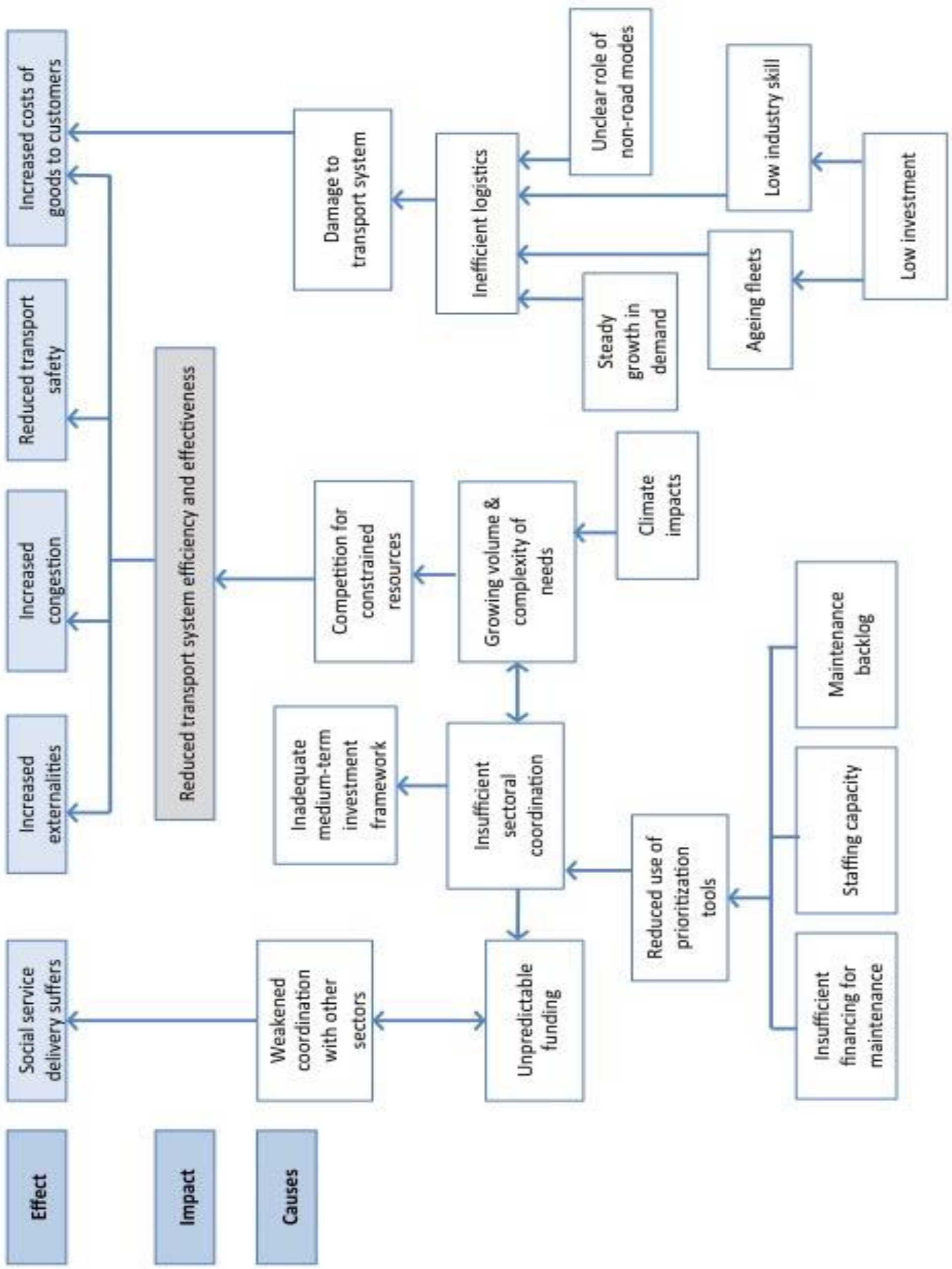
- Places an acceptable financial demand on all levels of government, regions, businesses, households and individuals;
- Takes into account available funding sources;
- Considers costs, including those that occur in other sectors;
- Enables the country's economic, social, environmental and cultural goals to be met in an affordable way to meet current and future needs; and
- Requires that all investments in transport are cost-effective and represent value for money;

SUSTAINABLE

- Contributes to a carbon neutral future and operates within environmental limits, using finite reserves of non-renewable resources wisely and, where possible, substituting them with renewable resources;

- Enables the access and development needs of individuals, businesses and communities with an appropriate mode of transport;
- Creates opportunities to reduce transport inequalities between individuals and communities;
- Safeguards Ethiopia's ecosystems and land; and
- Increases individual awareness and understanding of their role and responsibility in contributing to sustainable transport for Ethiopia and making transport choices accordingly;

APPENDIX B: PROBLEM TREE



APPENDIXC: Establishing Standardized Criteria for Determining Critical Assets

The purpose of establishing standardized criteria for determining critical assets is to identify those elements of the transport system that should they be damaged, they have a higher level of impact on the system as a whole, in a consistent approach for all transport sub-sectors.

The intent is to help determine where to focus limited resources based on systemic importance, and to help set the parameters of risk tolerance for the different elements of the transport system. Once identified, the critical infrastructure and key functions can be prioritized, or ranked, as to which is most important and in what context.

During the consultations, agreement was reached in regard to the criteria that will be used in all transport sub-sectors to determine critical assets. Three assessment categories were established for determining criticality:

Socioeconomic assessment (focused on connectivity): Infrastructure that is important to an area due to service to economic centers, the availability of a parallel (redundant) assets and whether or not the infrastructure assets supports community connectivity;

Operational considerations (focused on asset purpose): how often or how much the asset is used, its functional classification, whether it is a freight or passenger route or any other factors that could affect its importance to the region; and

Health and safety element (focused on function): Access to basic services and those that support evacuation, disaster relief and disaster recovery routes.

This was followed by development of a series of indicators for each category:

Table 1: Indicators for critical asset categories

Asset Name		
Category	Indicator	Score (High/Medium/Low)
Socio-Economic	Is a regionally important corridor	
	Functions as key community connection	
	Is linked to a regional, economic or major urban center	
	There is a parallel or equivalent asset that provides redundancy	
Operational	Functional classification	
	Usage	
	Condition	
	Has intermodal connectivity	
Health & Safety	Is an identified evacuation route	
	Has a disaster relief and recovery function	
	Provides access to health facilities	

APPLICATION OF CRITERIA TO ROAD CORRIDORS

Table 2: Criticality assessment of road corridors

Category	Indicator	RC 1	RC 2	RC 3	RC 4	RC 5
Socio-Economic	Is a regionally important corridor	H	H	H	H	H
	Functions as key community connection	H	H	H	H	H
	Is linked to a regional, economic or major urban center	H	H	H	H	H
	There is a parallel or equivalent asset that provides redundancy	L	L	H	H	H
Operational	Functional classification	H	H	L	L	L
	Usage	H	H	H	H	H
	Condition	H	H	H	H	H
	Has intermodal connectivity	n/a	n/a	n/a	n/a	n/a
Health & Safety	Is an identified evacuation route	H	H	H	H	H
	Has a disaster relief and recovery function	H	H	H	H	H
	Provides access to health facilities	H	H	H	H	H

Legend: RC1 = Central eastern corridor (Addis Ababa – Adama – Awash – Semera – Galafi)
RC 2 = Eastern corridor (Awash – Harar – Jijiga – Deghabur – Kebere Dahar – Gode)
RC 3 = Northern corridor (Addis Ababa – Debere Brehan – Kombolcha – Weldia – Mekele – Adigrat – Zalambessa)RC 4 = North western corridor (Addis Ababa – Debermarkos – Baher Dar – Gonder – Shire – Axum – Adawa)RC 5 = Western corridor (Addis Ababa – Ambo – Nekemet – Assossa – Kurmuk)