Enhancing the Climate Resilience of Africa's Transport Infrastructure

A new method allows policymakers to manage the risk imposed by extreme climate change events on roads and bridges in Sub-Saharan Africa.

Roads are a key asset for Africa - they connect villages to economic centers, people to hospitals, children to schools and goods to markets facilitating trade. This study considered 2.8 million km of roads in Sub-Saharan Africa, including new road construction outlined in the Programme for Infrastructure Development in Africa (PIDA) and assessed the impact of climate change on roads and bridges.

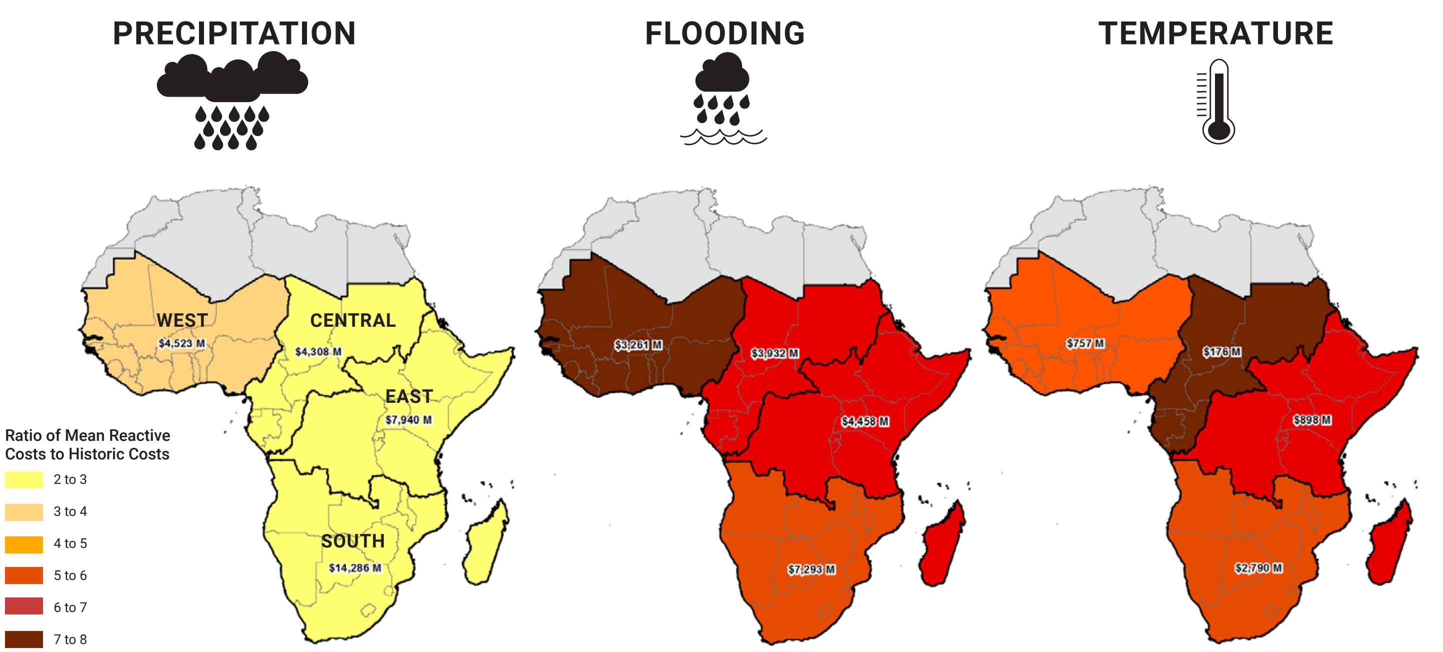
Climate change is expected to substantially increase disruption time of the network, shorten their rehabilitation life-cycle, and increase repair and rehabilitation costs. The study evaluates the economics of engineering solutions to build resilience to climate change impacts due to flooding, precipitation, and temperature and develops a methodology to assist decision makers in identifying the most cost-effective adaptation approach, comparing the cost of inaction (reactive response) to the net cost of investments in adaptation (proactive adaptation).

Key Messages:

- Adequate road maintenance is the most critical and most efficient way of reducing the impact of a changing climate on the road system.
- Proactive adaptation is a cost-effective option in virtually all countries in response to anticipated higher temperatures, and in at least eight countries in response to precipitation.
- Better information on the benefits of avoiding climate-related disruption can inform decisions on proactive adaptation

Climate Change Threatens to Increase Road Maintenance Costs by 270%

Values indicate the total effect of climate change on road maintenance costs in 2015$ (discounted at 6%) due to precipitation, flooding and temperature stress in Central, East, South, and West Africa. Colors indicate the ratio of reactive maintenance costs to historic costs for the respective stressor in each region. Flooding and temperature stressors are expected to result in significant increases in reactive costs compared to historic costs.



APPROACH

Climate Change Projections
Assemble climate change scenarios for temperature, precipitation, and flooding

"PIDA+" Network
Assemble data on trans-boundary road projects, country-level projects, and existing roads

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Risks of Inaction
Reactive response is the additional maintenance and repair made necessary by changes in climate.

Adaptation
Proactive adaptation involves changes to road design standards and investments in more resilient construction.

→

Decision Making Considering Road Disruption Effects
Compare the risks of inaction, with the costs and benefits of proactive adaptation action. The benefits include both the reduction in financial costs of maintenance and repair over time, and reduced road disruption, because the road is repair far less frequently if it is made resilient to climate change.

Step 1 – DATA

The study applies IPCC vetted climate change scenarios on the infrastructure data compiled for existing and planned new road networks, using the Infrastructure Planning Support System (IPSS), a quantitative, engineering-based analysis tool to understand the impacts of climate change on current and future roads, bridges, and other infrastructure.

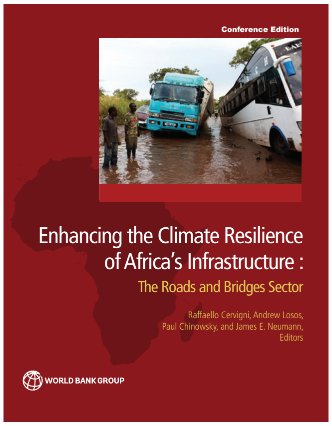
Step 2 – ANALYSIS

Costs imposed by climate change on the road infrastructure are estimated for two scenarios:

- **Reactive Response (Risks of Inaction)** - No proactive measures are taken to prepare the roads for climate change, and extreme events damage roads. Climate change impacts are quantified in terms of increased maintenance costs, relative to those that would be incurred under current climate, and incremental road disruption costs.
- **Proactive Adaptation (Investments in Adaptation)** - Anticipatory measures are taken to mitigate the effects of climate change and take advantage of any opportunities. Climate change impacts are quantified in terms of up-front costs of design changes, reductions in subsequent needs for repeated repairs and maintenance, and reductions in road disruption.

Step 3 – DECISIONS

Proactive adaptation makes financial sense if the construction cost of adapting to climate change is more than offset by the cost for maintenance, rehabilitation and repairs due to climate change impacts. The inclusion of traffic disruption in this analysis further strengthens the case for proactive adaptation. In particular, for high-traffic roads, even milder climate change can cause serious disruptions in the movement of people and goods, tilting the balance in favor of adopting more climate resilient engineering solutions, justifying the higher construction costs incurred when following a proactive adaptation response.



Effects of Climate Stressors On Roads

ROAD TYPE	INCREASED IMPACT BY CLIMATE STRESSOR	EFFECT
Paved roads	Temperature	Accelerated aging of binder
		Rutting of asphalt and bleeding and flushing of seals
	Precipitation	Increased average moisture content in subgrade layers and reduced load carrying capacity
	Flooding	Wash-aways and overtopping of road
Unpaved roads	Temperature	No effect
	Precipitation	Leads to increased roughness of the road surface increase average moisture content in subgrade layers, and reduced load-carrying capacity
	Flooding	Wash-aways and overtopping of road

APPROACH (continued)

The financial case for proactive adaptation depends on the climate change scenario considered. The case will be stronger under scenarios of more severe climate change (as there will be higher cost savings over the lifecycle of the project); and weaker in scenarios of less pronounced change (smaller savings, relative to the upfront adaptation/construction cost). For some road projects, there will be net financial savings over the assets' lifecycle in all climate scenarios. In these cases, the case for adaptation is unequivocal. Considering only the perspective of life-time financial costs leaves out the fact that more resilient road assets shorten the down time of the transport network, because climate stressors do not take the road out of service. A shorter repair and maintenance downtime for roads reduces the disruption of supply chains, and restores the accessibility of schools and hospitals.

Therefore, the last step in the study is to consider both the financial benefits and the benefits of reduced disruption time in a decision-making context called a "breakeven analysis." This is particularly important in projects where the financial case for adaptation is sensitive to the climate scenario considered. In particular, for high-traffic roads, even milder climate change can cause important disruptions in the movement of people and goods. In these situations, the balance can be tilted in favor of adopting more climate resilient engineering solutions, in spite of the higher construction costs incurred when following a proactive adaptation pathway.

What Does it Take to Integrate Climate Change into Road Project Design?

Implementing the approach proposed by this report scale—which involves many interactions among the components of the road network system—may appear to be overly complex. But implementation at the project scale has grown more tractable recently. The modeling components required for a project- or country-level climate change analysis for roads consist of the following:

- A set of downscaled climate projections for the project's or country's relevant geographic region.
- Information on the baseline capital and maintenance costs for constructing roads to alternative design specifications.
- A simple project design and cost model that can reproduce existing cost estimates from pre-feasibility studies, and can estimate how costs would vary with alternative design specifications that incorporate adaptation. If the complexity of the design precludes the development of a simple design and cost model, several estimates of alternative designs could be developed using more detailed tools.

The requisite sets of climate projections have become increasingly available, including those used for this report. These data sets will soon be made available Africa-wide through a central data repository (http://sdwebx.worldbank.org/climateportal/). Appropriate road analysis tools have also become increasingly available and can be calibrated using the same data utilized in feasibility studies. Finally, this study has developed a relatively transparent set of adaptation measures for each climate stressor, that can be used as a template for a wide range of applications.

FINDINGS

Adequate road maintenance is the most critical and most efficient way of reducing the impact of a changing climate on the road system. In the absence of an adequate maintenance regime, the damage caused by climactic events is exacerbated. The uncertainty related to climate change further reinforces this dynamic. Thus, maintenance of pavements and sealing activities; regular maintenance of bridges, culverts and drainage structures to ensure they are functional and not obstructed; maintenance and improvement of slope protection works; and systematic assessments to identify and incrementally address vulnerable and critical road sections are the first defense to climate risks. This report finds that even assuming adequate maintenance regimes (thereby standardizing the analysis across countries), climate change will cause substantial disruptions in network connectivity and increases in repairs and rehabilitation costs. In fact, most African countries are well below maintenance standards, which will make climate change impacts even more severe. This suggests that adequate, climate-resilient maintenance should be a key priority as countries operationalize their Nationally Determined Contributions (NDCs), and should be supported by climate finance when available.

Proactive adaptation in response to temperature increase is a no regret option. Modifying the design in response to an anticipated higher temperature is a low or no-regret option for paved roads in virtually all countries and the vast majority of climate scenarios, including both the PIDA transboundary corridors and the planned expansion/upgrade of the national networks. The reason is that the savings accrued over the road life cycle more than offset the higher construction costs, even if the measures are adopted now, before significant temperature increases are experienced. In other words, the study shows that it is already appropriate to design road infrastructure for the higher temperatures that climate change will bring. Not doing so may cause the need to repair damages related to higher temperature.

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Impact of Precipitation on Bridges

There are approximately 330,000 bridges in the existing roads network across Sub-Saharan Africa. Thirty-one percent of these are critical links for primary or secondary roads. Bridges are mainly vulnerable to bank erosion and scour related to flow events, and therefore impacts due to flow characterization caused by the precipitation stressor were used in the analysis. Compared to historic costs, increases in costs due to climate change range between 1.5 and 7 times for the least severe and most severe climate scenarios, respectively. Additionally, disruption times are often much higher for bridges than for roads because of the critical nature of bridge crossings in road networks.

The case for proactive adaptation in response to precipitation is not as clear cut, and needs to be assessed case by case. Because of the fundamental uncertainty regarding future climate, it is not possible to be as definite on how to proactively design for precipitation. Rainfall varies all over the continent, but in at least eight countries (Angola, Nigeria, Botswana, Togo, South Sudan, Mozambique, Benin, and Cameroon) it is clear that even moderate changes in the climate will induce significant precipitation-related disruption. In these countries it would be appropriate to start proactively adapting the road system. In other countries, more detailed analysis is needed to identify where, when and how to invest in resilience most appropriately. Some roads in some areas may well already benefit also from pro-active adaptation.

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Better information on the benefits of avoiding climate-related disruption can inform decisions on proactive adaptation. This report develops a methodology to evaluate the merits of proactive adaptation in the context of an uncertain future climate. The methodology can be applied in a straightforward manner to decisions about specific investments, once more granular information is available on:

- the lifetime cost of road assets;
- the value of the freight and passenger traffic expected to use those assets,
- the criticality of the road segment on the one hand and the level of network redundancy on the other hand, and
- how climate stressors (precipitation, flooding, extreme temperatures) are likely to affect both the road asset and its use.

This study evaluated the economics of engineering solutions to build resilience (such as increasing the drainage capacity of a road; better crowning a road to enable water to the sides; hardening river banks to avoid flooding; using road binders better adapted to extreme temperatures). This focus is justified by the need to avoid locking road projects in climate-vulnerable engineering solutions that could be very costly to reverse later. Other adaptation options that African countries could assess, in terms of their cost-effectiveness of reducing climate risk, include:

- Sector and spatial planning - positioning roads where they are not likely to be harmed by climate; building-in redundancies, i.e., multiple ways to get to the same place
- Non-engineering solutions - traffic control, like restricting trucking on certain roads; rerouting traffic; regularly cleaning the drains and tunnels
- Enabling environment – policies and regulations that facilitate the professional management of road systems, including good contracting, regular maintenance, and inspection.

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NEXT STEPS

The results of the study provide a powerful motivation for changing the way road infrastructure is designed, to take better account of climate change. Making this change will require strong support of governments, project developers, and financiers. That is why the World Bank, the UN Economic Commission for Africa, the African Development Bank, and key donors have announced a cooperative effort to develop the Africa Climate-Resilient Investment Facility. The facility's activities will be based in Addis Ababa, Ethiopia, have regional Centers of Excellence throughout Africa, and will meet the need for expert assistance, high-quality climate and road infrastructure data, and practical on-demand consulting support to enhance the resilience of new infrastructure.

> "African countries do not need to slow down the pace of infrastructure investment. As long as climate risk analysis is fully integrated in the project cycle and in pre-feasibility studies of individual investments, climate risks can be significantly mitigated in a cost-effective manner."

What comes next?

Promoting adaptation to climate change in the planning and design of infrastructure is likely to require a change in mindset, away from consolidated behavior and practices, with the goal of better integrating the expertise of the relevant professions, such as climate scientists and design engineers. Because such a paradigm shift is likely to have a considerable gestation time, the time to act is now, with priority assigned to the following selected areas of interventions.

1. **Develop technical guidelines on the integration of climate change in the planning and design of infrastructure in climate-sensitive sectors.** A multi-stakeholder technical working group could be established to develop voluntary technical guidelines on how to apply the notions of climate resilience, discussed at length in this book, to real-life infrastructure planning and design.

2. **Promote an open-data knowledge repository for climate-resilient infrastructure development.** To bring down the cost of the analysis needed to integrate climate considerations into infrastructure development, there is a need to establish common data sources (on climate scenarios, road infrastructure, standard construction costs, etc.), which could be made available to the public on open-data platforms and hosted by African institutions (such as UNECA's African Climate Policy Center).

3. **Establish an Africa climate resilience project preparation facility.** The facility, which would be adequately financed with grant or concessional resources, could have different windows to cater to the specific needs of different sectors or for different stages of the infrastructure development cycle. For example, the facility could provide support to climate-resilient infrastructure master plans or to the integration of climate resilience into individual projects.

4. **Launch training programs for climate-resilient infrastructure professionals.** To ensure adequate strengthening of the technical skills that are required to enhance the climate resilience of infrastructure, one or more training programs could be established for professionals involved in the planning, design, and operation of climate-sensitive infrastructures.

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