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Prioritization of Road Interventions in Nampula and Zambezia, Mozambique under Changing Flood Risk and Other Deep Uncertainties

Xavier Espinet & Julie Rozenberg

GGKP Conference - November 2017

Objective: Improve rural accessibility and agriculture production…

Government of Mozambique requests loan to World Bank for rural road development

Government, Country Office and Transport team decide the area

World Bank team prepares project:
- Scoping the project
- Economic analysis
- Financial management
- Env. and social safeguard
- …

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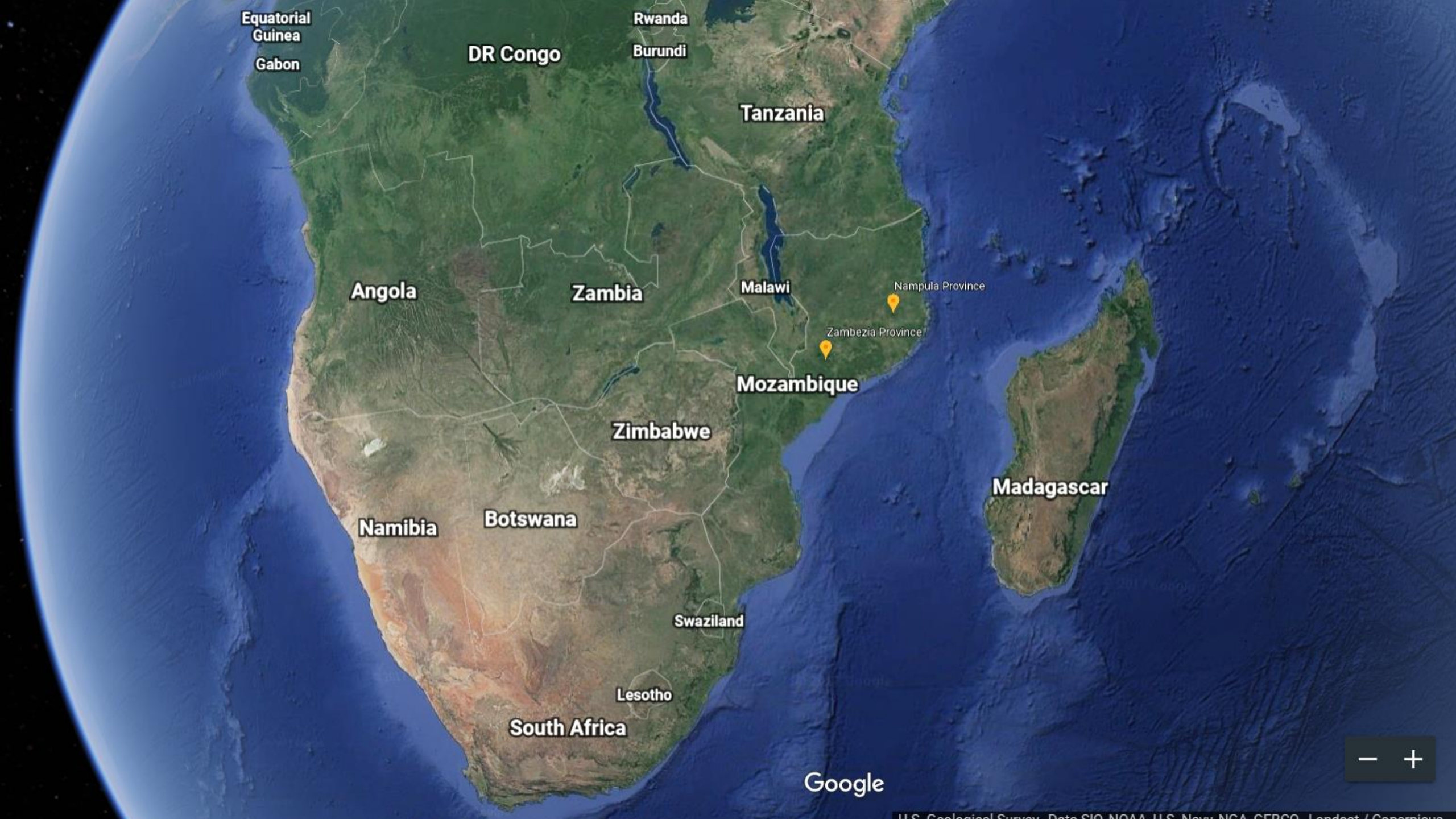
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Namibia
Botswana
Swaziland
Lesotho
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… despite recurrent floods

The World Ban[redacted] reached out to Chief Economist to fi[redacted] method to prioritize road based on [redacted]tion

Additionally, C[redacted] to incorporate risk reduction cons[redacted]e economic analysis

AND TO INCLUDE CLIMATE CHANGE!

Where and how much to invest?

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Objective:

1) Prioritize districts where investments will have the highest impact
   a. Criticality: proximity to ag potential, lack of redundancy, poverty
   b. Risk: exposure and vulnerability to floods

2) Choose which investment are the most robust in each of the chosen districts using DMDU approach
   a. Cost-benefit analysis accounting for benefits in terms of risk reduction and ag productivity
   b. Stress-test to find the investment which have high NPV under many future conditions

- Briceño-Garmendia, C, Moroz, H, Rozenberg, J. 2015. “Road Networks, Accessibility, and Resilience: The Cases of Colombia, Ecuador, and Peru - An LCR Regional Study.” Washington, DC: World Bank.
- Rozenberg, Julie; Briceno-Garmendia, Cecilia M.; Bonzanigo, Laura; Moroz, Harry Edmund. 2017. *Improving the resilience of Peru's road network to climate events*. Washington, D.C. : World Bank Group

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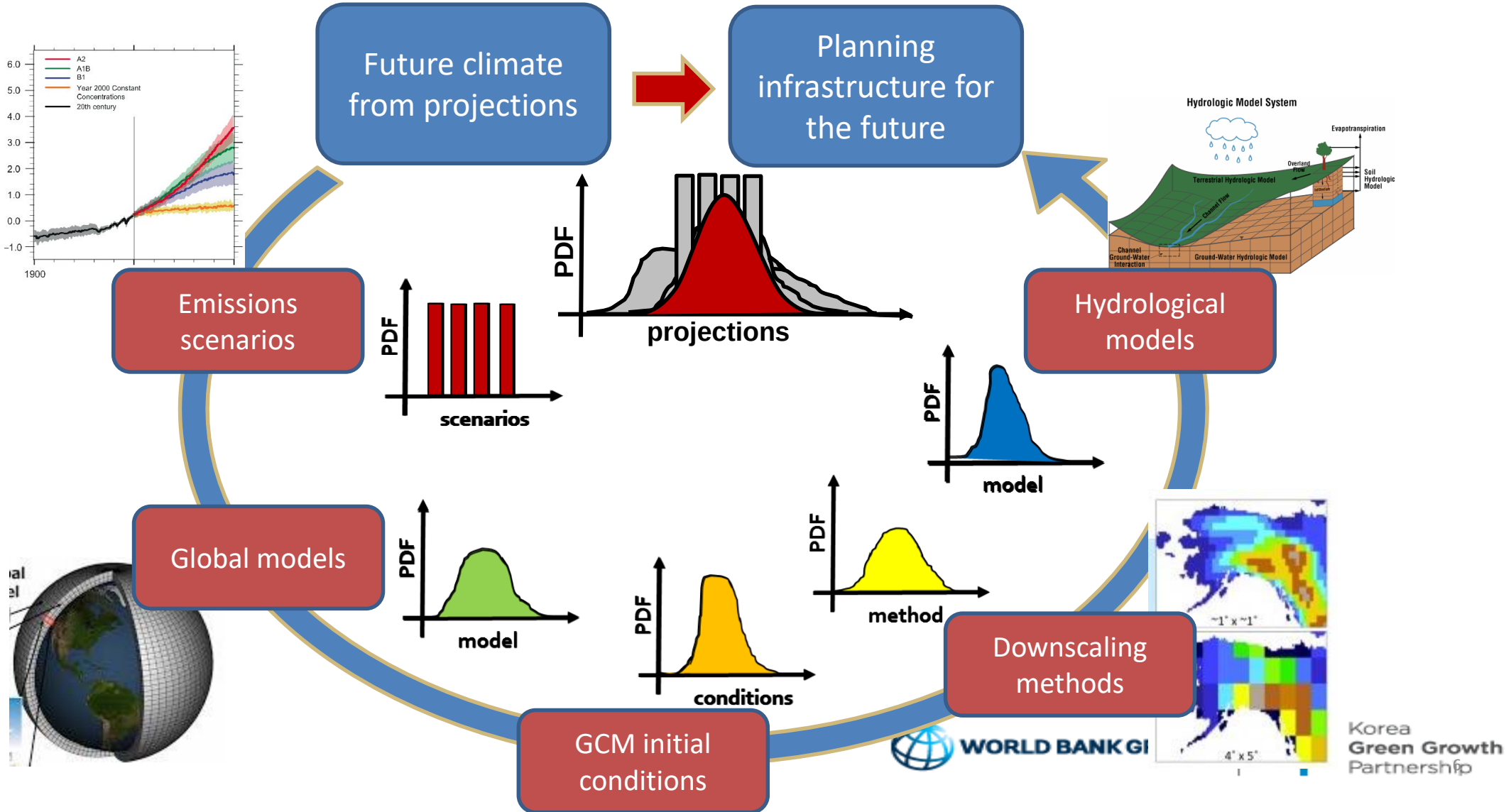
Main Problem! Uncertainty, uncertainty, uncertainty…



Main Problem! Uncertainty, uncertainty, uncertainty…

High level of uncertainty associated with climate change impact models

- Difficulty for decision-makers to **understand** the true nature of **the problem**
- Difficulty to **define future standards** to adapt infrastructure to the changing climate
- Difficulty to **choose the best strategy** to withstand future weather events

If a man will begin with certainties, he shall end in doubts, but if he will be content to begin with doubts, he shall end in certainties

~ Francis Bacon

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Decision Making under Deep Uncertainty

- THE SOCIETY:

DMDU

a multi-disciplinary association of professionals
dedicated to improving
decision making under deep uncertainty

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Decision Making under Deep Uncertainty…

"Predict Then Act"

What will the future be? → What is the best near-term decision? → How sensitive is our decision to our predictions?

…RUNS THE ANALYSIS BACKWARDS

Decision Making Under Uncertainty (DMU)

What are the available strategies? → Identify vulnerabilities of these strategies → Develop strategy adaptations to reduce vulnerabilities

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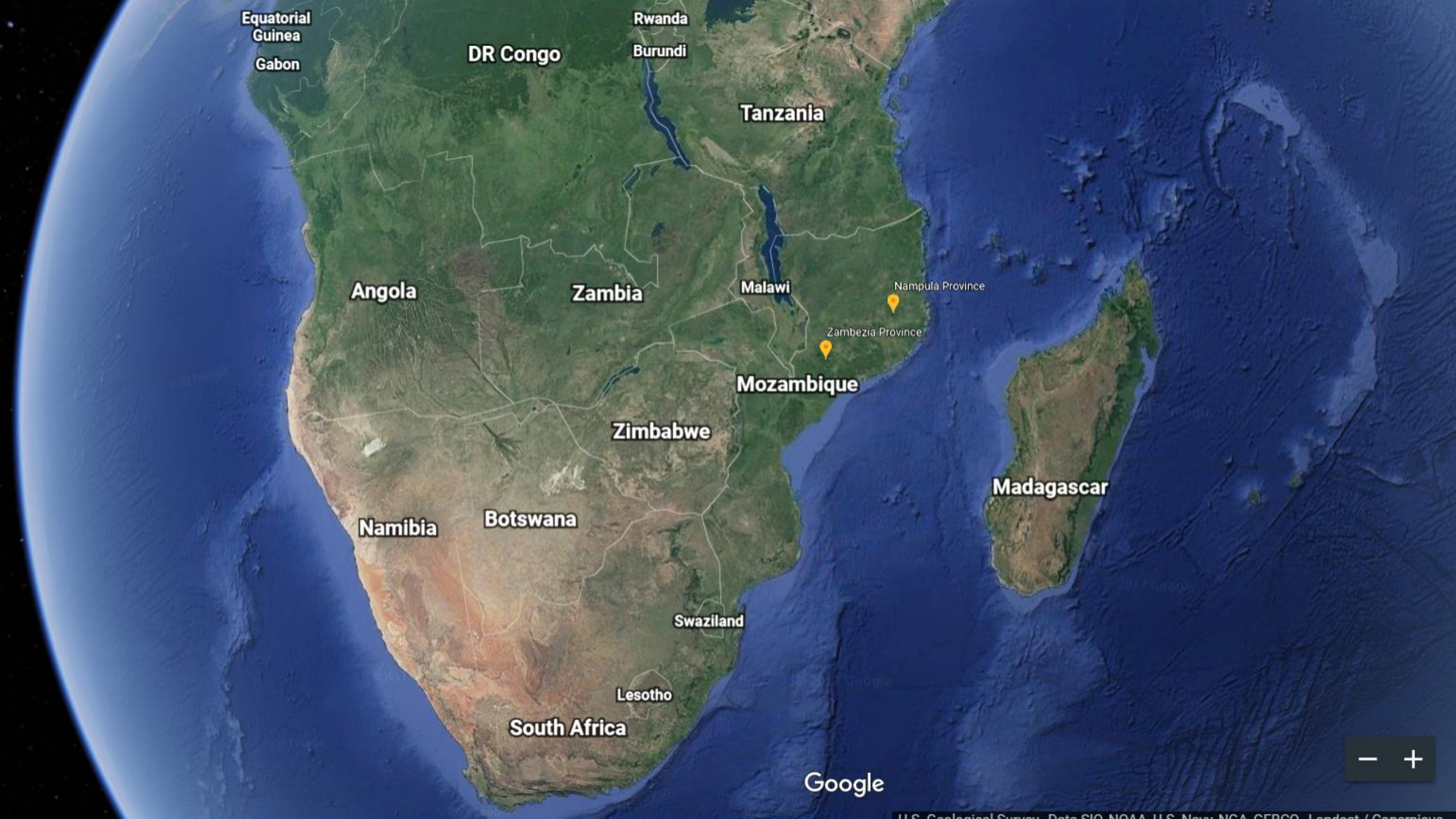
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Pre-identification of combinations of investments

During a workshop local stakeholders chose, for each district, several combinations of:

- Upgrade to surface treatment
- Upgrade to gravel road
- Partial rehabilitation of earth roads
- Clean and repair bridges
- Replace culverts

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Cost-benefit analysis under uncertainty

Benefits (over 20yrs) :

- Maintenance savings
- Reduction of road user cost (RUC)
- **Reduction of flood damage to infrastructure (EAD)**
- **Reduction of flood disruption cost for users (EAUL)**

Costs (over 20yrs) :

- Initial capital cost
- Periodic rehabilitation

Uncertainties:

- Climate projections: current, low, medium and high
- Flood duration, -50% to 50%
- Traffic growth, 0 to 6%
- Traffic to agriculture growth elasticity, 0.5 to 1.5
- Discount rate, 3 to 12%
- Repair time, -50% to 50%
- Capital Cost, -50% to 50%
- Bridge Repair, -50% to 50%

We generated 2,000 scenarios

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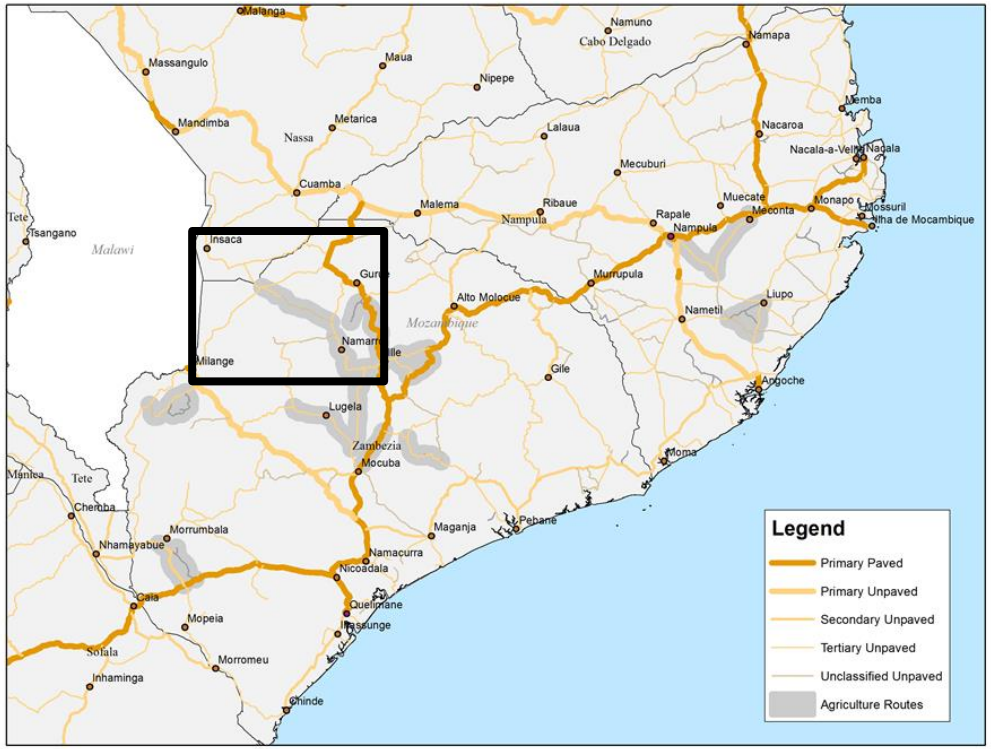
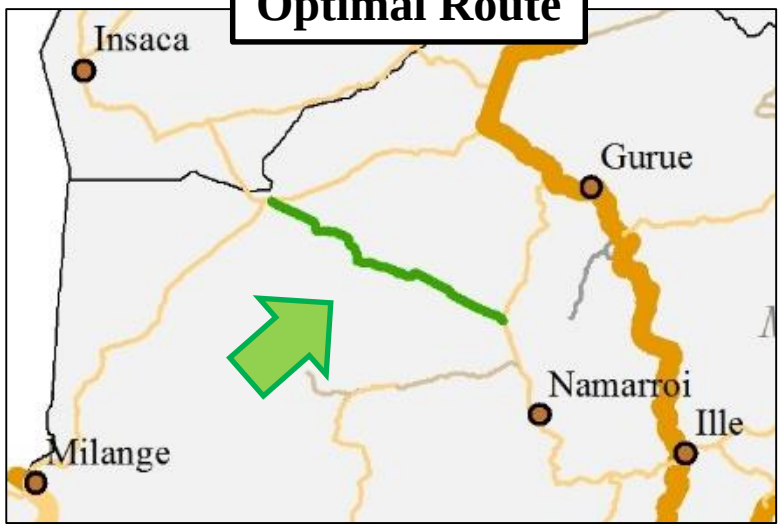
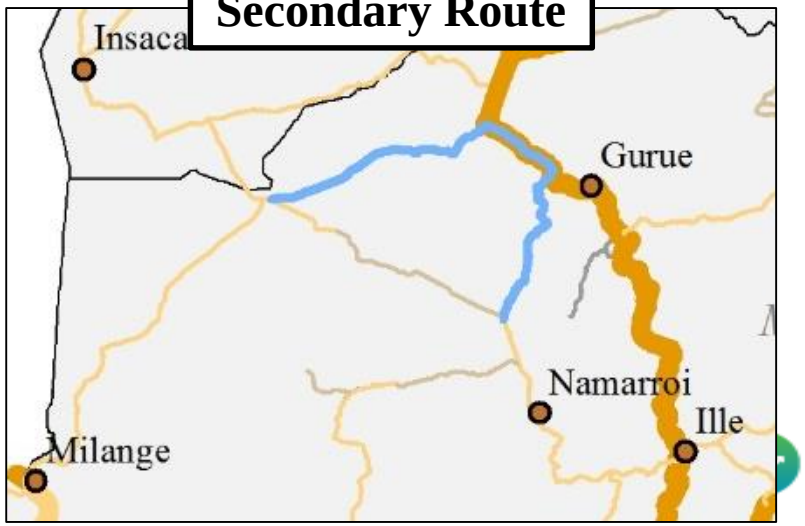
Transport network model



Optimal Route



Secondary Route



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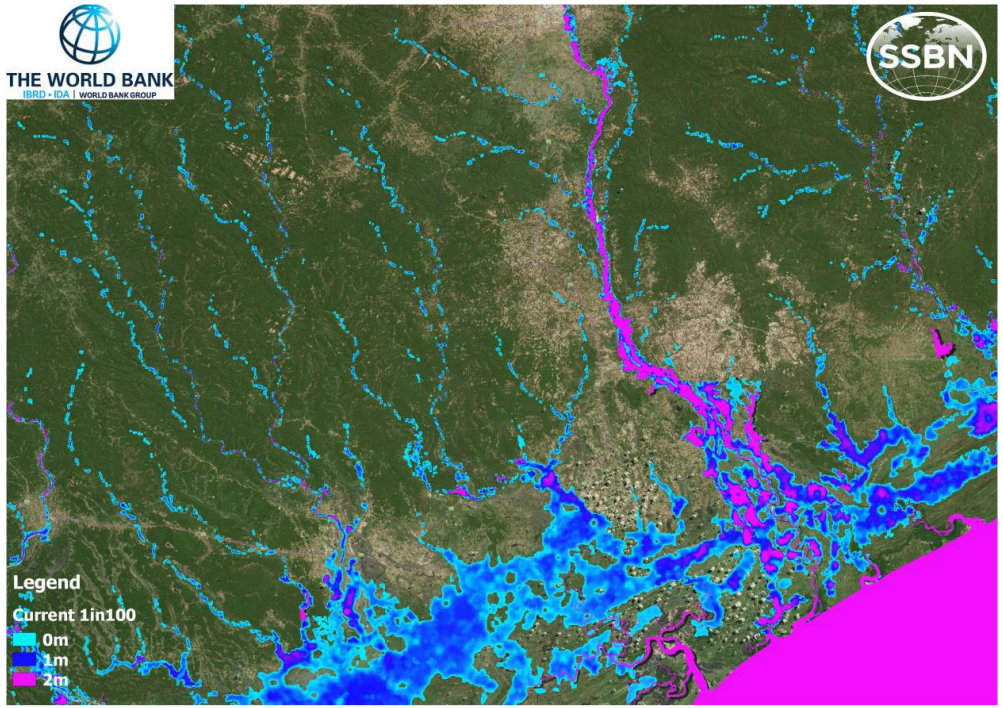
Flood risk

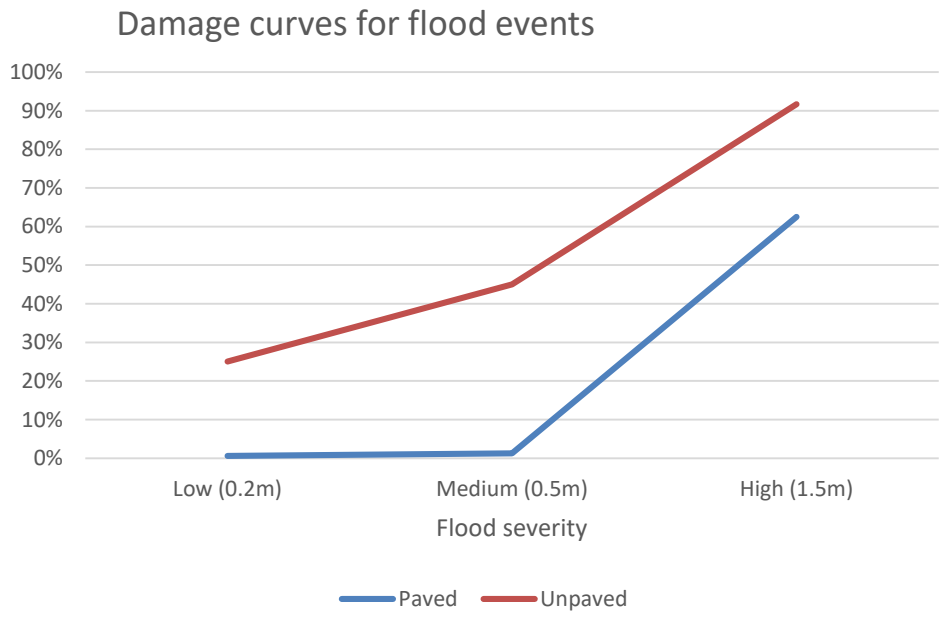
Flood maps based on

- Past rainfall events
- Climate Change future projections (low, medium and high scenarios)
- 10 return periods: 5, 10, 25, 50, 75, 100, 200, 250, 500 and 1000



Flood damage to the infrastructure

- Using existing Bridge Inventory Attributes
- Estimating location and condition of culverts
- Using simple damage functions (from local expertise)
- Using local cost and standard of rehabilitation and repair (from local expertise)



Rehabilitate (USD/km)	paved	unpaved
primary	320,000	60,000
secondary	320,000	60,000
tertiary	250,000	50,000
unclassified	250,000	50,000

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Murrumbala – Benefits breakdown

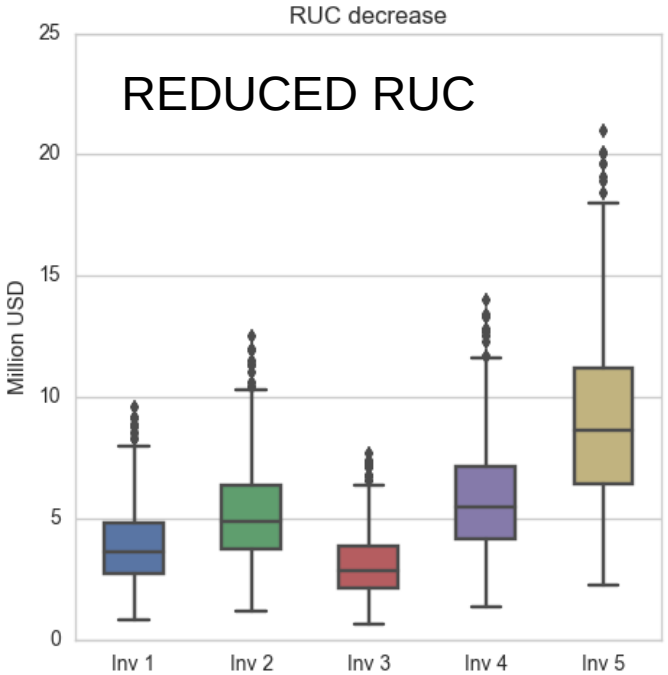
Inv. 1: Paving of 45km + partial rehabilitation of 551km

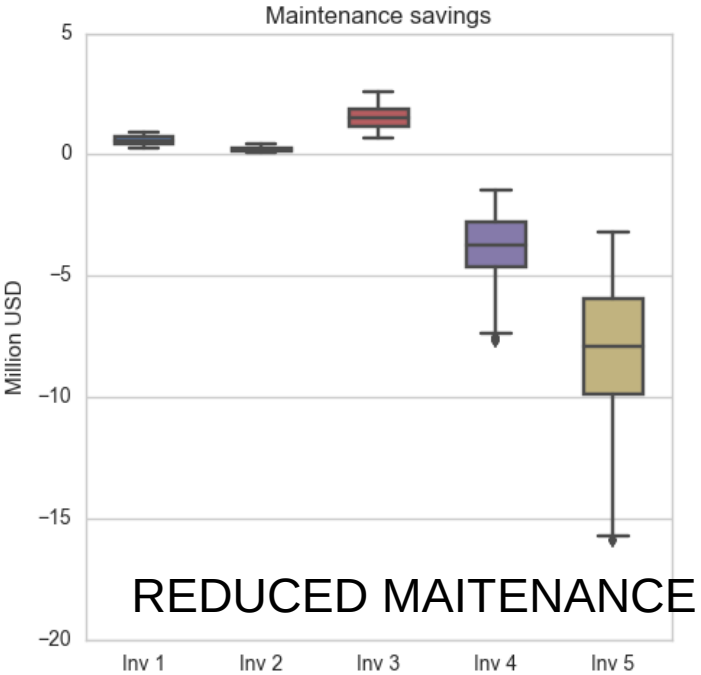
Inv. 2: Paving of 66km + partial rehabilitation of 530km

Inv. 3: Upgrade all culverts, clean and repair all bridges + partial rehab of 596km

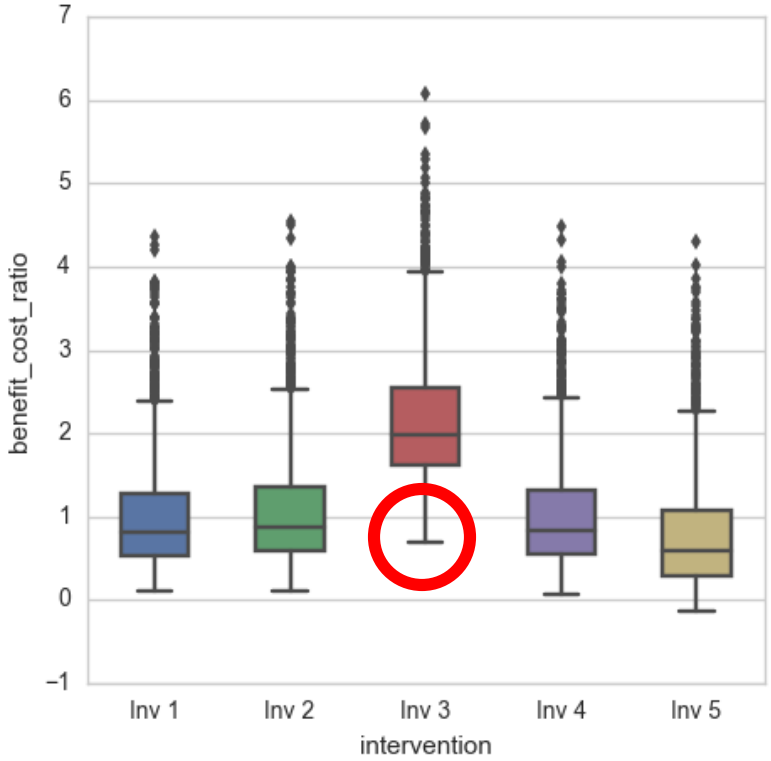
Inv. 4: Graveling of 213km + partial rehab of 383km

Inv. 5: Graveling of 383km + partial rehab of 213km

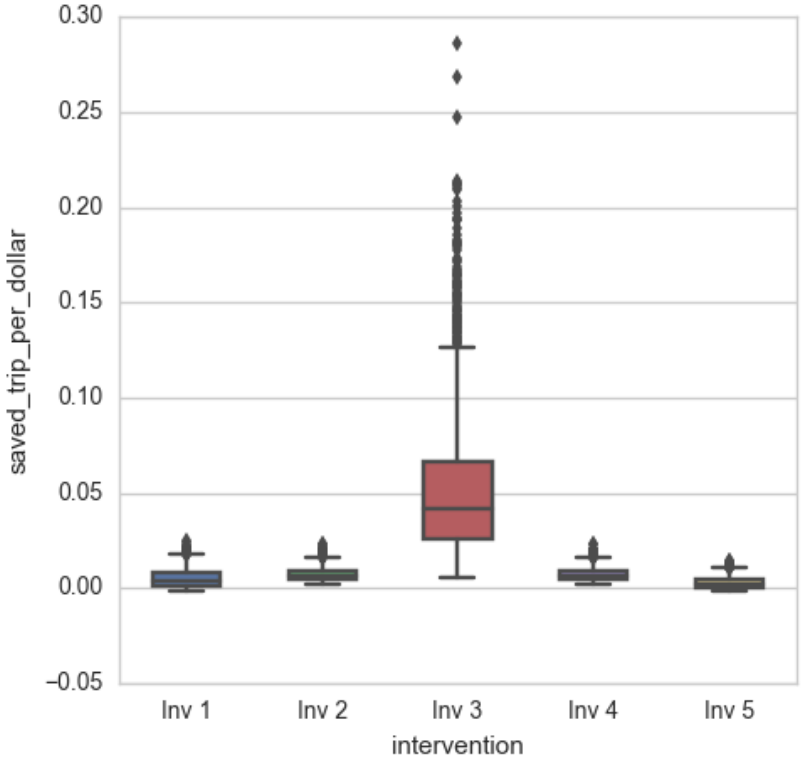




Murrumbala – Benefit cost ratio (BCR) and Saved Trips



BENEFIT COST RATIO



SAVED TRIPS PER DOLLAR

Investment 3 (bridges and culverts) is the best option in 98% of scenarios and has a BCR >1 in 95%.

It has the highest saved trips/dollar ratio.

Minimax regret option.

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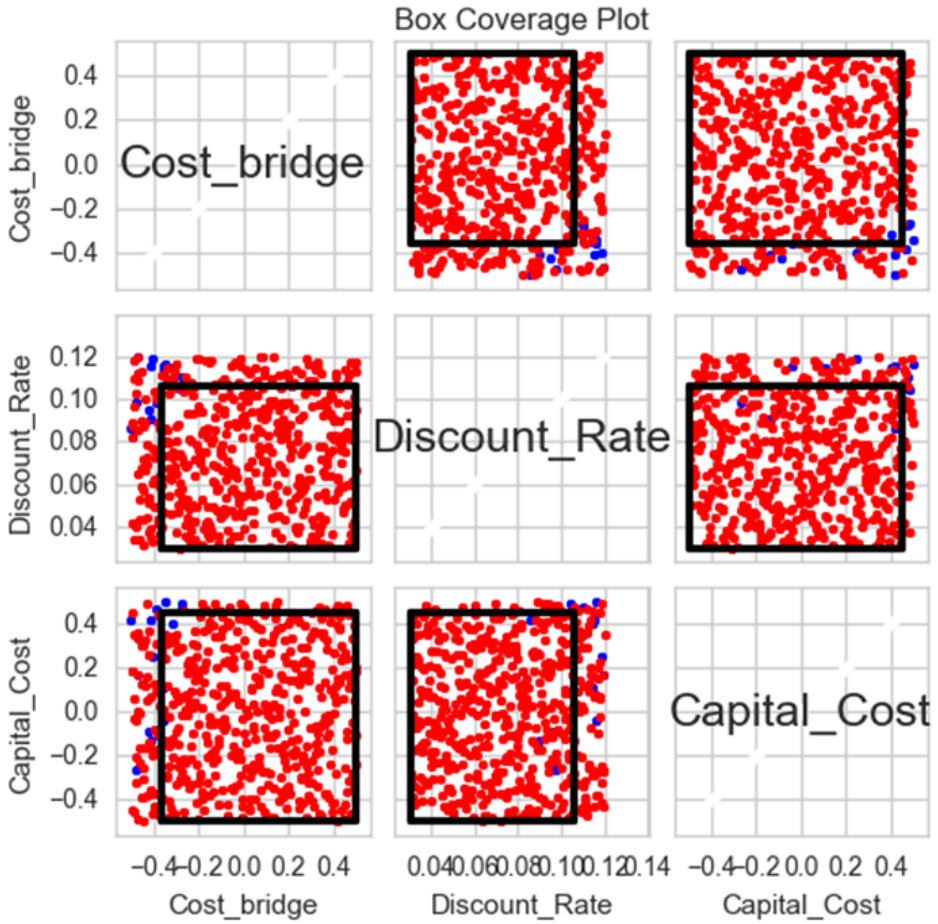
Murrumbala – Stress-test results (PRIM)

- Investment 3 (bridges and culverts) has a BCR >1 in 95%.
  - Stress-test: in 5% of the scenarios Inv. 3 can have a BCR<1. Those are scenarios with high discount rate (>11%), low cost of (reactive) bridge repair (40% lower than current estimates) and high bridge construction cost (>45% of current estimates). It is highly unlikely to see those conditions met together so the we are confident the BCR of Inv. 3 will always be >1.



https://github.com/RANDCorporation/PRIM

Conclusions

- Investments in repairing and rehabilitating drainage structures are the most robust and cost effective interventions – INCREASING MAITENANCE!

- In most cases, transport network benefits are **2 times** traditional bene[illegible]cluded in road project's economic analysis
- In best case, the benefits from risk reduction are **6 times** traditiona[illegible] included in road project's economic analysis

- Global problems (aka. deep uncertainty) require out-of-the-box sol[illegible]

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THANK YOU

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