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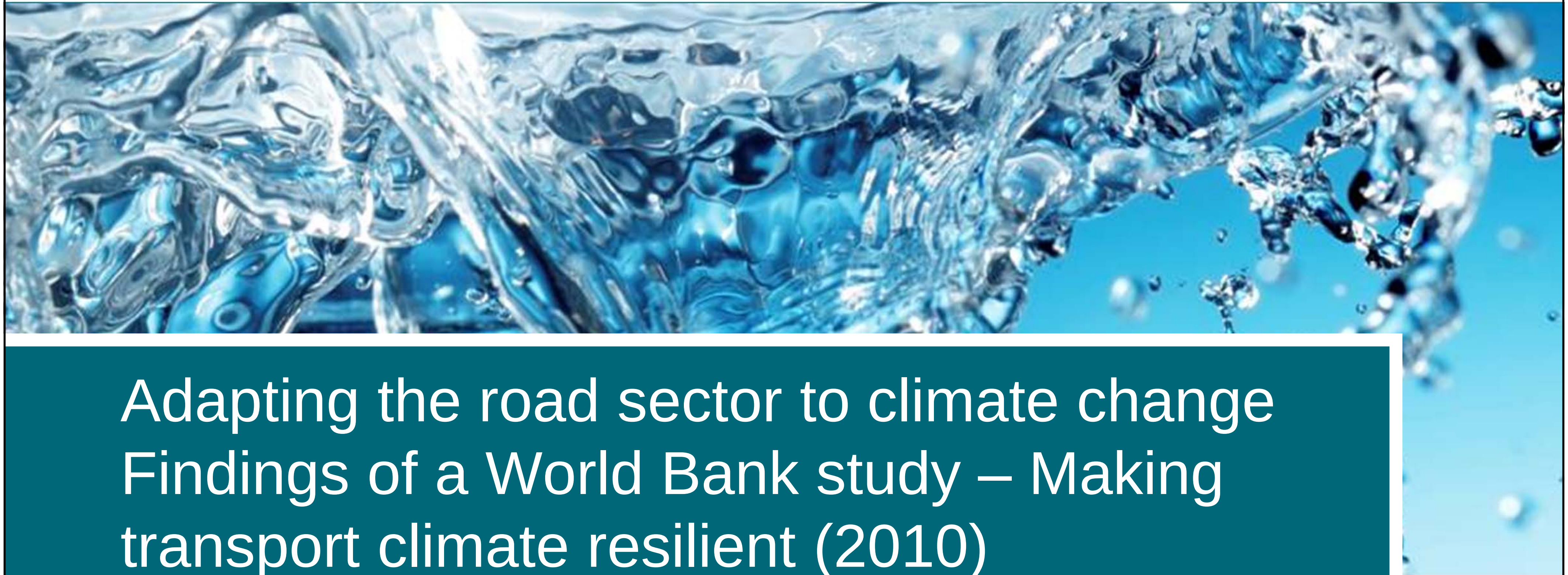


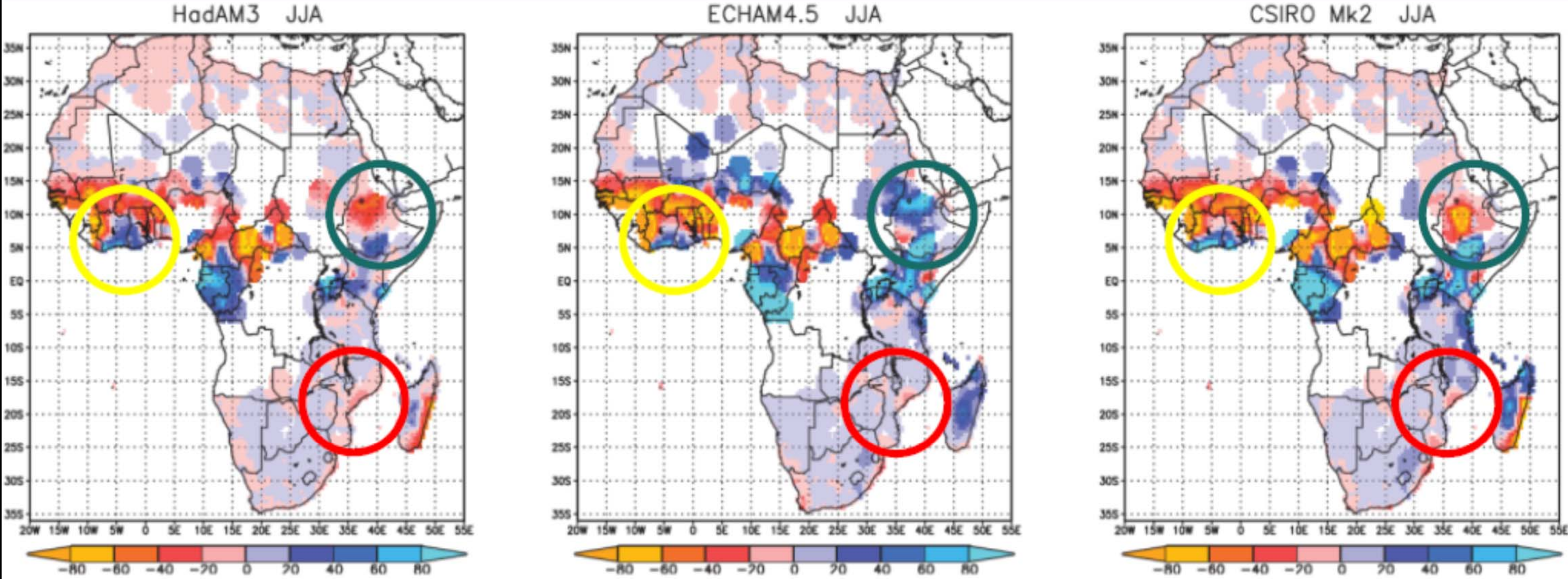
Adapting the road sector to climate change Findings of a World Bank study – Making transport climate resilient (2010) (Mozambique, Ghana and Ethiopia)

Darren Lumbroso, HR Wallingford

Steven Wade, HR Wallingford

Possible future

Predicted anomaly of mean monthly precipitation (mm) for the summer rainy season, JJA, 1990-2089



Source: UNDP (using subset of IPPC climate models

Observed climate trends the last 30 to 40 years

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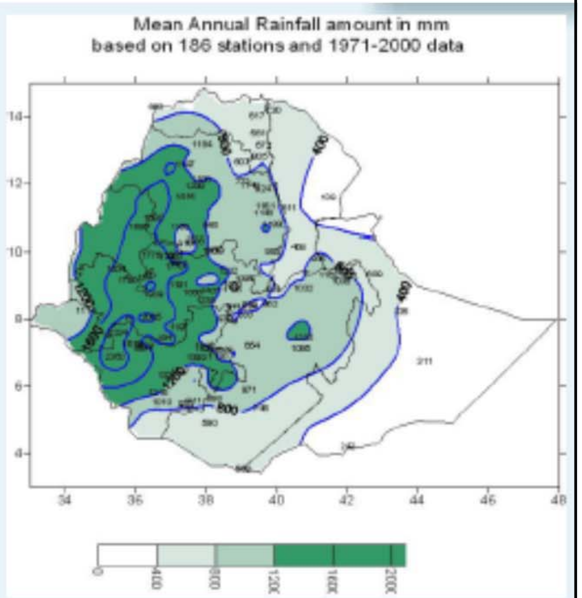
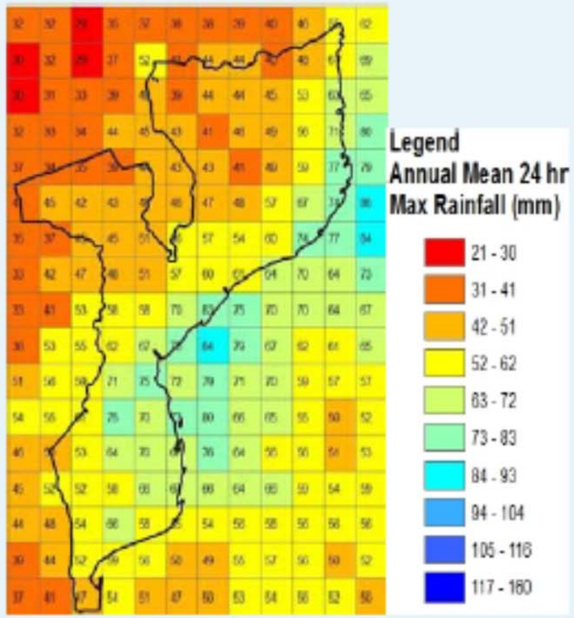
- > Increased average temperatures, 0.1 to 0.3^{O}C per decade
- > Increased number of hot days and nights
- > Larger variation from year to year in extreme events
- > No significant trend in annual rainfall





Climate scenarios and model projections

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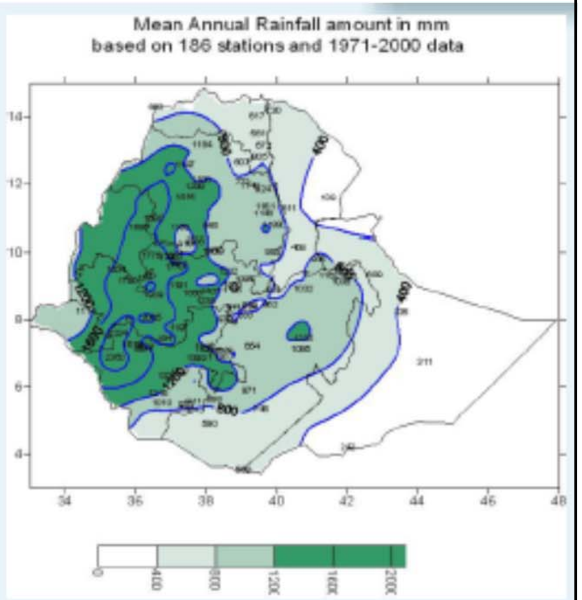
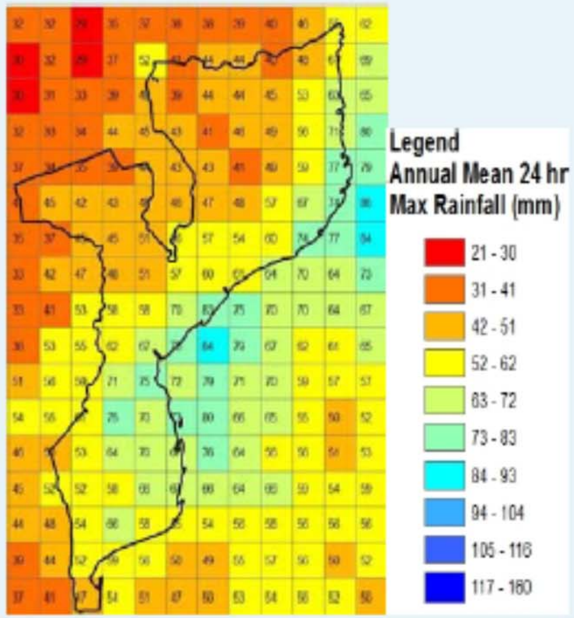
- > Mean temperatures increase with around 2^{O}C till 2050
- > Rainfall patterns are uncertain to predict, but probably increased annual and maximum 24 hour rainfall in most areas
- > IPPC sea level scenarios vary greatly e.g. increases between 20 cm and 100 cm in 2060 in Mozambique
- > The number and/or intensity of extreme events will increase for cyclones: less frequent and more intensive





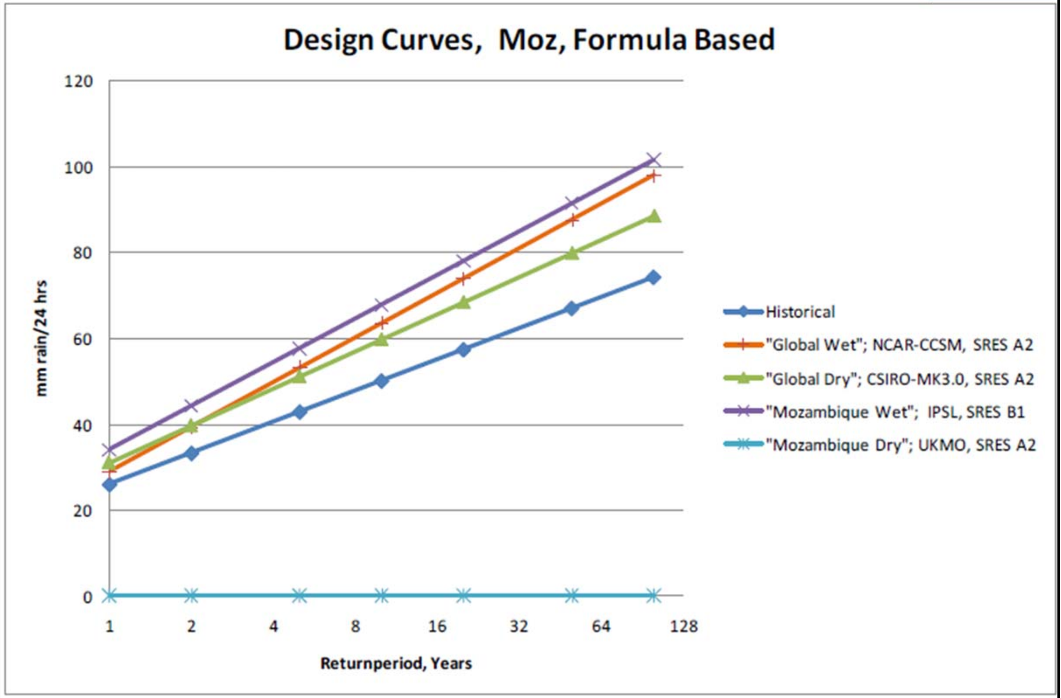
Future return periods of design storms in 2050

Today's design storms for roads could be:

> For 10 year storms 2 to 3 times more frequent

> For 20 year storms 2 to 3 times more frequent

> For 100 year storms 3 to 6 times more frequent



Road assets affected

Road network elements

> Pavements and road base

> Bridges

> Culverts

> Slopes (stability)/landslides

> Surface drainage

General challenge for road assets

Success of roads relies on:

> Choice of alignment, design and construction

> Climate and topography of location

> Traffic loading (axle loads)

> Maintenance

Largest problem for current road assets:

> Poor maintenance

> Overloading of roads

> Lack of repair

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Challenges for road assets amplified by climate change

Climate change challenges for roads caused by:

> Raising temperatures

> More intensive precipitation

> Sea level rise, cyclones, ocean tides

Climate change adaptation measures

Climate variable	Road asset	Current climate impact to road	Current counter-measure	Climate change	Climate change impact to asset	Recommended climate change countermeasure
Average temperature	Bridges	Thermal expansion of materials	Expansion joints	Increasing mean temperature	Increase expansion	Account for temp increase in design phase
	Pavement design	Deformation surface, cracking	Proper asphalt mix design		Increase in surface deformations	Use current temperatures range during service/ reconstruction intervals (due to low technical lifetime of payments)
# of very hot days	Road construction maintenance crews working days	Limited working hours during very hot days		Increase in # Hot days	Decreased available working hours	
	Pavement design	Deformation surface, cracking	Proper asphalt mix design		Increase in surface deformations	Use current temperatures range during service/ reconstruction intervals (due to low technical lifetime of payments)

Change in temperature

Increase of temperatures by 2 to 3^{O}C

- Impact need for expansion flexibility for bridges
- Requirements to stiffness of asphalt

Measures:

- Long term:
  - Change designs for temperature requirements for bridges
  - No change in design methodology needed
- Short term:
  - Use more adequate asphalt mix when resurfacing roads

No significant adaptation costs may occur

Change in precipitation

Increased peak flows and floods

> Scour and bank erosion for bridges

> Hydraulic capacity reduced

> Floods/wash away of bridges and culverts

Measures:

> Long term:

- Revise future design criteria as more information on climate becomes available
- Upstream river training to stabilize channels

Short term:

- More maintenance will reduce risks generally
- Spot upgrades in a few critical areas based on cost/benefit assessments

Change in precipitation intensity

Increased rainfall intensity

> Flooding and wash away of roads

Measures:

> Long term:

- Improved future design of surface drainage. In cities co-ordinated with urban planning
- Better slope protection for new constructions, e.g. increased plantation
- More critical hydrological analyses before constructing in river beds
- Increased research in suitability of local materials for community roads

Short term:

- More maintenance
- Spot upgrades in critical areas

Sea level rise, cyclones, ocean tides

Raising sea levels and cyclones (but ocean tides are the big challenge!)

> Flooding and wash away of roads

Measures:

> Long term:

- Construct coastal defences e.g. sea walls
- Relocate infrastructure (and population)
- No future construction in high risk areas

> Short term:

- More maintenance
- Spot upgrades in critical areas e.g. elevate low-lying critical road links
- Ensure sufficient monitoring stations to collect reliable data
- Improve hydrological data and models

Cost of adaption to climate change

Baseline scenario – no climate adaptation

> “in 2050, the climate is as today”

Climate adaptation scenario – based on different strategies:

> (i) All adaptation measures are implemented
> (ii) Optimal adaptation strategy is implemented (based on cost benefit analysis)

Cost of climate change adaptation = Cost of climate adaptation scenario – Cost of baseline scenario

Cost of adaption to climate change

Summary of construction cost distribution today and assessment of cost increase (full adaptation) due to climate change in 2050 for upgrading gravel to paved road (cost per km/road)

Description	Percentage of total costs today	Likelihood of cost increase
General & Site Clearance	10%-25%	No increase
Earthworks	10%-15%	Can be significant
Sub Base, Road Base and Gravel Wearing Course Bituminous Surfacings and Road Bases	35%-60%	Can be significant
Drainage	5%-15%	Can be significant
Structures	5%-10%	Can be significant
Day works	1%-3%	Can be marginal
Road Furniture & Miscellaneous	1%-5%	No increase
Total	**100%**	**2% - 10% (Low climate effect)** **9% - 19% (High climate effect)**

Cost of adaption to stakeholders

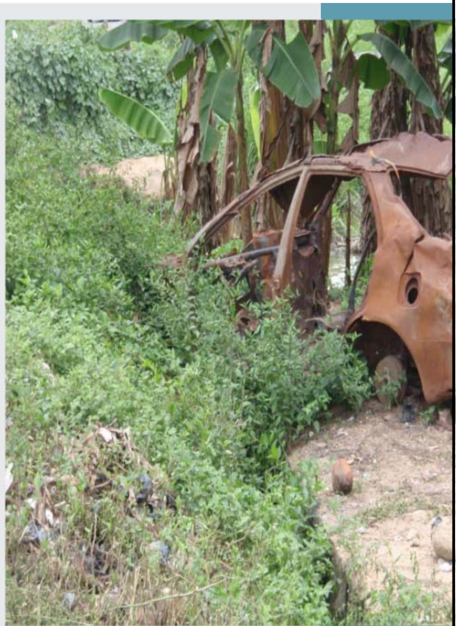
	Road Agencies	Road users	Third parties
Existing network	• increased annual reconstruction costs • higher unit reconstruction costs • reduced value of infrastructure in 2050 • increased maintenance costs	• reduced service level (until adaptation has taken place)	• more detours • impacts from adaptation measures (until adaptation has taken place)
New network	• higher unit construction costs/more frequent reconstruction • increased maintenance costs	• none – if current service levels are maintained	• none – if adaptation does not impact on transport users
Total	carry almost all costs	Carry some costs	carry almost no costs

Implications for assets – Temperature and precipitation

> Yearly reconstruction costs for existing roads will increase (shorter lifetime and higher unit costs)

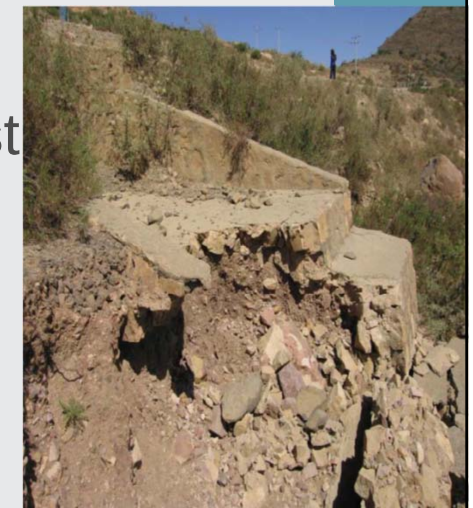
> Adaptation strategy: infrastructure is reconstructed when destroyed or lifetime exceeded using newest climate data

> New climate resilient roads are more costly (higher unit costs)



For areas exposed to adaptation measures:

- Frequent revision of design storm parameters
- Adapting fully to climate changes is not necessarily the optimal strategy for all road elements but probably for most (this needs further research and location specific cost benefit analysis)
- Protect infrastructure by using more and better maintenance



Sound decision making for roads also in the future

Sound planning still builds on (Cost-Benefit) analysis of:

- > Future demand for transport, including composition (e.g. axle loads, heavy/light vehicles, etc.)
- > The climatic environment (now and in the future with climate change) at the location
- > Alignment options possible
- > Available design and construction technologies as well as practise competence –balancing design and maintenance costs

Risk issues in decision making

Climate change should influence decisions and policies with regard to:

> Willingness (and ability) to pay for reducing future risks –value of avoiding increased probabilities of climate related incidents

> Trade off between current and future spending –maintenance effort versus infrastructure strength

> Development in high risk areas – protective measures versus abandon areas

Steps to ensure more climate robust decisions:

– Identify sensitive areas

– Assign range of occurrence probabilities of climate changes over lifetime

– Undertake different designs depending on climate probabilities

Implications – Sea level rise and ocean tides

Raising sea levels and variations in ocean tides -decisions have to be made

> Protect the infrastructure by coastal defences or over time relocate infrastructure (and population)

Implications – Main research needs

Research to strengthen knowledge about current climate – as a starting point

- Consistent data collection
- Hydrology data and models

Short-term recommendations

- Spend more on maintenance – it is already cost-efficient today
- Maintenance is to cope with existing climate, changed designs with the future climate
- More critical analysis of alignments before constructing to avoid high climate risk locations
- Do not reconstruct existing network because of climate change before the network is worn out –maybe with a few carefully selected exceptions
- Existing good and comprehensive design manuals may be adjusted –after due consideration to future service levels
- Do more research in predicting sedimentation and run off in the landscape

Long-term recommendations

- Review climate related parts of design guidelines at 5 to 10 year intervals to take account of observed climate trends
- Establish more focused maintenance strategies
- Develop more reliable hydrology models to improve decisions on future road alignments
- Develop and test methods to improve maintenance practices (e.g. scour protection of bridges)

Strategic recommendations

- A strategy needs to be flexible, adaptive and robust and acknowledge that climate models show large variability in future rainfall patterns which is the most important design parameter
- A climate resilient road in the future (i.e. up to 2050) will not be that different from a climate resilient road now
- The current state-of-the-art technical and economic approaches and methods to assess projects/initiatives in the decision processes will also be valid in the coming years -but need to be based on robustness to various climate conditions

When to consider climate change Kalantari (2001)

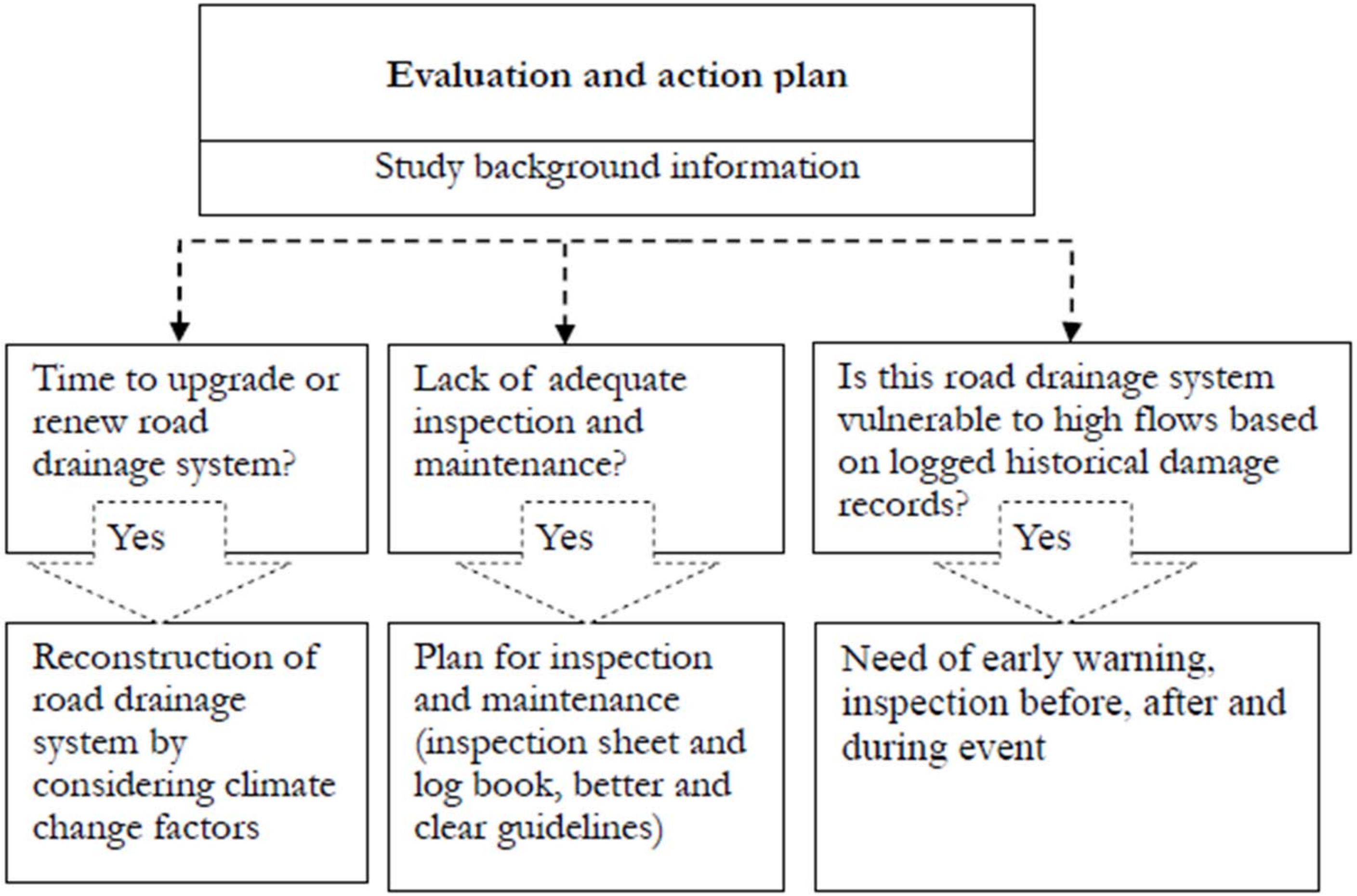


Fig. 10.Scheme for a proposed evaluation and action plan for a road drainage system.

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Any questions?

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