World Bank Study: Making Transport Climate Resilient

Adapting the road sector to climate change

Presented by:
Fang Xu, Economist, Africa Region Office, fxu@worldbank.org
Karsten Sten Pedersen, Project Director, COWI A/S, ksp@cowi.dk
Making Transport Climate Resilient
Presentation

1. Introduction to the study
2. Climate trends and climate scenarios
3. Road asset components and road challenges
4. Road climate challenges and adaptation measures
5. Costs of adaptation to climate change
6. Road sector decisions with larger climate variability
7. Policy implications and recommendations for adaptation
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A study for Sub Saharan Africa – 3 Countries

Study objectives:
- establish knowledge base
- deliver guidelines for road transport planning and policy decisions
- contribute to raising awareness

Outputs to contribute to answering – given existing climate predictions:
- what are the types and magnitude of climate change relevant for roads sector?
- what are the most important challenges for roads assets?
- what are the costs for adapting to climate change in the road sector?
- what are the costs to road users with and without adaptation to climate change?
- what are the policy implications of adaptation?
- what are the recommended measures in the short and the long term?
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Climate Trends and Climate Scenarios - examples

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

Source: UNDP (using subset of IPPC climate models)
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Climate Trends and Climate Scenarios

**Observed climate trends the last 30-40 years:**
- increased average temperatures, 0.1-0.3°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/model predictions:**
- mean temperatures increase with around 2°C till 2050
- rainfall patterns are uncertain to predict, but probably increased annual and max 24 hour rainfall in most areas
- IPCC 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 & more intensive
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Predictions: 4 Climate Scenarios' Impact on Road Designs

Future return periods of design storms in 2050:

- today's design storms for roads:
  - for 10 year storms will be 2-3 times more frequent
  - for 20 year storms will be 2-3 times more frequent
  - for 100 year storms will be 3-6 times more frequent
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Road Asset Elements Affected

Road network elements
- pavements & road base
- bridges
- culverts
- slopes (stability)/landslides
- surface drainage
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:
- overloading of roads
- poor maintenance
- lack of repair
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Climate change Challenge for Road Assets

Current challenges for road assets are amplified by climate change

Climate change challenges for roads:

• raising temperatures
• more intensive precipitation
• sea level rise, cyclones, ocean tides
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#### Climate Change Impacts and Adaptation Measures – Example: Temperatures

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

- Increase of temperatures by 2-3°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
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Change in Precipitation Intensity – Structures

• 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
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Change in Precipitation Intensity – Roads

- Increased rain intensity
  ➔
  flooding and wash away of roads
  more land slides

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
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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
Base scenario – no climate adaptation:
• "in 2050, the climate is as today"

Climate adaptation scenario – based on different strategies:
A. all adaptation measures are implemented
B. optimal adaptation strategy is implemented (based on CBA)

Cost of climate change adaptation =
• cost of climate adaptation scenario – cost of base scenario
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Additional Construction Costs for a Paved 2L Road

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)

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

With very simplistic assumptions: NPV of full adaptation costs 2010–2050 amounts to around 2 years of current total road budgets - increase over time as climate change develops because of stronger measures required and growing networks.
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#### Costs of adaptation – Stakeholders

<table>
<thead>
<tr>
<th></th>
<th>Road Agencies</th>
<th>Road users</th>
<th>Third parties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing network</strong></td>
<td>• increased annual reconstruction costs&lt;br&gt;• higher unit reconstruction costs&lt;br&gt;• reduced value of infrastructure in 2050&lt;br&gt;• increased maintenance costs</td>
<td>• reduced service level (until adaptation has taken place)</td>
<td>• more detours&lt;br&gt;• impacts from adaptation measures (until adaptation has taken place)</td>
</tr>
<tr>
<td><strong>New network</strong></td>
<td>• higher unit construction costs/more frequent reconstruction&lt;br&gt;• increased maintenance costs</td>
<td>• none – if current service levels are maintained</td>
<td>• none – if adaptation does not impact on transport users</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>carry almost all costs</td>
<td>Carry some costs</td>
<td>carry almost no costs</td>
</tr>
</tbody>
</table>
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Implications for assets – Temperature, 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 CBA analysis!)

Protect infrastructure by using more and better maintenance
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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

for a situation with project (including various levels of adaptation to climate change) compared to a no-project situation
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
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)
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Implications – Main Research needs

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

• consistent data collection
• hydrology data and models
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Short run (next 5 years) initiatives:

- 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
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Strategic Recommendations – Long Run

Long run recommendations:

• review climate related parts of design guidelines at 5–10 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)
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Strategic Recommendations – Summary

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 (till 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**