Climate Change Impacts and Adaptation Issues for Infrastructure Assets

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Issues of Development and Climate

- Long-life assets (e.g. infrastructure) are essential for development
- Huge investments are being committed in developing countries
- Most infrastructure assets are exposed to climate
- Development and climate change would impact long-life assets
- Infrastructures have low autonomous adaptive capacity
- Impact are more directly associated with climatic extremes rather than averages
- Infrastructures are not assessed for climate impacts and adaptation
- Higher economic damages in developed / industrialized areas but higher human damages in less-developed areas
- Infrastructures are also part of adaptation strategies
Categories of Climate Impacts

• Environmental quality (e.g., Air pollution, water logging or salinity increase, etc.)
• Linkage systems (e.g., threats to water supply or storm effects on power supply, increased competition for critical inputs)
• Social infrastructure (e.g., changed energy/water/health requirements, heat island effects, disruptive severe weather events, reductions in resources for other social needs, environmental migration, changes in local ecologies)
• Physical infrastructure (e.g., flooding, storm damage, changes in the rate of deterioration of materials, changed requirements for such infrastructures as water supply)
• Economic infrastructure and comparative advantages (e.g., costs and risks increase, markets or competitors affected)
Adaptation Strategies

- Facilities and linkages against extreme weather-related events
- Contingency planning (such as stockpiling)
- Changes in financial mechanisms to increase resiliency
- Increased efficiencies in thermal conditioning
- Relocation and industrial restructuring
- Planning for likely increase in demands
- Adaptation by industry with adjustments to changes in climatic parameters
- Attention to the security of transportation and other linkage infrastructures
- Risk financing and risk mitigation
Projected changes in temperature and precipitation on a regional scale for India

Projections of seasonal precipitation for the period 2041-60, based on the regional climate model HadRM2

Source: India’s Initial National Communication, 2002
## Climate Projections: Summary

**Maximum temperature:** Increase by 2-4°C during 2050s in regions above 25°N.

**Minimum temperature:** Increase up to 4°C all over the country. May exceed 4°C over southern peninsula, northeast India and some parts of Punjab, Haryana and Bihar.

**Monsoon Rainfall:** Marginal changes in monsoon months (JJAS)

- **Large changes** during non-monsoon months

**Number of rainy days:** Decrease in the number of rainy days over a major part of the country. More in western and central part (by more than 15 days) while near foothills of Himalayas (Uttaranchal) and in northeast India the number of rainy days may increase by 5-10 days.

**Extreme Rainfall events:** Overall increase in the rainy day intensity by 1-4 mm/day except for small areas in northwest India where the rainfall intensities decrease by 1 mm/day.

**Cyclonic storms:** Increase in frequency and intensity of cyclonic storms is projected
# Secondary Climate Changes

<table>
<thead>
<tr>
<th></th>
<th>Humidity</th>
<th>Water Availability</th>
<th>Sedimentation</th>
<th>Flooding/Water Logging</th>
<th>Vegetation</th>
<th>Mangroves</th>
<th>Marine Life</th>
<th>Structural Stability</th>
<th>Land Slide</th>
<th>Land Erosion</th>
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<tbody>
<tr>
<td><strong>Temperature Rise</strong></td>
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<td><strong>Precipitation Increase</strong></td>
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<td><strong>Sea Level Rise</strong></td>
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<tr>
<td><strong>Increase in Extreme Events</strong></td>
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</table>
Future impacts on a system = fn. \((SDV_i, CCV_j, SCV_k)\)

where,

- **SDV** = Projections for relevant Sustainable Development Variables
  - \(i\) = Technology, institutions (e.g. for governance and implementation), economic instruments (e.g. insurance, etc), other policies (e.g. forestation, intensive cropping, etc.)

- **CCV** = Projections for relevant Climate Change Variables
  - \(j\) = Temperature, rainfall, sea level rise, extreme events, secondary variables (e.g. vegetation, land slides, water logging, etc.)

- **SCV** = Projections for relevant System Condition Variables
  - \(k\) = Life, maintenance levels, usage patterns, soil type, etc.
## Reverse Impact Matrix

<table>
<thead>
<tr>
<th></th>
<th>Environmental Variables</th>
<th>Project Components</th>
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</thead>
<tbody>
<tr>
<td>Dependent Variables</td>
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<tr>
<td>Forcing Variables</td>
<td>Environmental Variables</td>
<td></td>
</tr>
<tr>
<td>Project Components</td>
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</tbody>
</table>

**Conventional Environmental Impact Matrix**

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**Environment:**

- **Project Components**
- **Environmental Variables**
- **Forcing Variables**
Case Study: Konkan Railway

- 760 Kms along Western coastal ghats
- $745 million project
- Considered an engineering marvel with:
  - 179 main bridges
  - 1819 minor bridges,
  - 92 tunnels (covering 12% of total route)
  - >1000 cuttings (224 deeper than 12 meters)
  - Longest tunnel is 6.5 Km long
  - Longest bridge is over 2 Km.
  - The pillars of the tallest viaduct bridge are more than 64 meters high.
## Climate Change: A case of Konkan Railway

<table>
<thead>
<tr>
<th>Climatic Parameter</th>
<th>Impact Parameter</th>
<th>Intervening Parameter</th>
<th>Impact on KRC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature Increase</strong></td>
<td>High evaporation rate</td>
<td>Stability and Strength of the building materials</td>
<td>Buildings gets weakened. More and frequent repair and maintenance.</td>
</tr>
<tr>
<td></td>
<td>Surface and ground water loss</td>
<td>Crop productivity in the region may be affected</td>
<td>Agricultural freight traffic</td>
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<tr>
<td></td>
<td>Need for Air-conditioning</td>
<td>Passenger traffic may shift to Air conditioned class</td>
<td>Affects efficiency, carrying capacity and composition.</td>
</tr>
<tr>
<td><strong>Rainfall Increase</strong></td>
<td>Ground and surface water level change</td>
<td>Flooding and water logging, Erosion reduces quality of land cover</td>
<td>Buildings affected, structural damages may take place. Increased maintenance and other related costs.</td>
</tr>
<tr>
<td></td>
<td>Improved water availability in the region</td>
<td>Agricultural production</td>
<td>Changes in agricultural freight traffic.</td>
</tr>
<tr>
<td></td>
<td>Humidity increase</td>
<td>Uncomfortable climatic conditions, Vegetation growth along the track</td>
<td>Passenger traffic affected, increased maintenance cost.</td>
</tr>
<tr>
<td><strong>Sea Level Change</strong></td>
<td>Land erosion</td>
<td>Tracks tunnels and bridges may be affected</td>
<td>Increased maintenance.</td>
</tr>
<tr>
<td></td>
<td>Flooding</td>
<td>Land stability, and land slides</td>
<td>Damage to infrastructure, Reconstruction and relocation.</td>
</tr>
<tr>
<td></td>
<td>Water logging</td>
<td></td>
<td>Delays, risk increase.</td>
</tr>
<tr>
<td><strong>Extreme Events</strong></td>
<td>Cyclone and high velocity winds and storms</td>
<td>Damage to buildings, communication lines etc</td>
<td>Disruption of services, repair and reconstruction costs.</td>
</tr>
<tr>
<td></td>
<td>Cloud bursts</td>
<td>Land erosion, floods, and land slides</td>
<td>Extensive damage to infrastructure, High cost of repair and reconstruction.</td>
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</tbody>
</table>
Application of Reverse Impact Matrix to Konkan Railway

**Forcing Variables**

<table>
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<td>Temperature</td>
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<td>Extreme events</td>
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<td>Water logging</td>
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<tr>
<td>Vegetation growth</td>
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<td>Land slide</td>
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<tr>
<td>Safety/Efficiency</td>
<td></td>
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<tr>
<td>Maintenance</td>
<td></td>
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<tr>
<td>Traffic volume</td>
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</tbody>
</table>

**Dependent variables**

- Temperature
- Rainfall
- Sea level rise
- Extreme events
- Water logging
- Vegetation growth
- Land slide
- Safety/Efficiency
- Maintenance
- Traffic volume

**Environmental Variables Project Components**

- **A. Increase in mean**
  - More number of days with >200 mm rainfall
  - Less number of days with >200 mm rainfall
  - Very high number of days with >200 mm rainfall
  - Very less number of days with >200 mm rainfall

- **B. Increase in variance**
  - More number of days with >200 mm rainfall
  - Less number of days with >200 mm rainfall
  - Very high number of days with >200 mm rainfall
  - Very less number of days with >200 mm rainfall

- **C. Increase in mean and variance**
  - More number of days with >200 mm rainfall
  - Less number of days with >200 mm rainfall
  - Very high number of days with >200 mm rainfall
  - Very less number of days with >200 mm rainfall
Presently 20% of repair and maintenance expenses on tracks, tunnels and bridges are due to climatic reasons.

Following the accident in 2003, the maximum permissible train speed in monsoon is reduced from 120 Km/h to 75 Km/h.

Identification of the vulnerable spots and installation of “Safety Wires”. Present vulnerable regions in the northern zone are shown on the map. Future rainfall pattern shows that such events are likely to occur more frequently and with higher intensity.

Present adaptation is limited to technological measures.
Key Impact parameters for Konkan Railway

• Konkan Railway route experiences heavy rainfall in monsoon
• In 23 June, 2003, landslides lead to accident caused 54 deaths
• The key climate parameter causing impact is “number of days having more than 200 mm rainfall”. Models show that this is likely to increase in future due to climate change
• Landslides also occur due to unsustainable land-use and forest management practices
• Combination of climate change and development pathway compound impacts
## Alternative Development Pathways

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Key Drivers</th>
<th>Implications on critical parameters of the scenarios and modeling analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA2: Reference scenario</td>
<td>GDP growth, Energy efficiency, Non-fossil fuels vs. fossil fuels, Oil consumption, Technological change, Movement on the fuel ladder</td>
<td>Sectoral demands (↑↓), investment limits (↑↓), fuel supply (↑↓), Forest cover (↓), Efficiencies of technologies using oil and gas (↑)</td>
</tr>
<tr>
<td>IB1: Sustainable Development scenario</td>
<td>Strong environmental awareness and conservationist values, Environmental integrity, consumption changes, dematerialization, cooperation, Shift away from fossil fuels, Local capacity building, Rural energy and electricity development</td>
<td>Environmental constraints (↑), Forest cover (↑), energy and materials content of goods/services (↓), electricity consumption due to efficiency improvements (↓), Transmission and Distribution losses (↓), Penetration of clean and renewable technologies (↑), organic fertilizer use (↑)</td>
</tr>
</tbody>
</table>
Stylized interaction of relevant CCV with SDV to keep the impacts within system resilience levels for the Konkan Railway under IA2 (Business-as-usual) scenario.

Rainfall variable projections akin to IPCC A2 from *Rupa Kumar et al., 2003*
Forest cover in the year 2000 for concerned districts from *Status of Forest Report, 2002*
Stylized interaction of relevant CCV with SDV to keep the impacts within system resilience levels for the Konkan Railway under IB1 (Sustainable development)

Rainfall variable projections akin to IPCC B2 from Rupa Kumar et al., 2003
Forest cover in the year 2000 for concerned districts from Status of Forest Report, 2002
Long-life assets commissioned now will have higher failure rates when they become old.

Climate change will exacerbate maintenance costs in future

Development pathway would further compound the impacts
Economic Losses and Probability of Occurrence

- Reference scenario (RS)
- RS with adverse CCV and strongly favourable SDV
- RS with adverse CCV and adverse SDV (SDV not considered)
- RS with adverse CCV and adverse SDV

Economic losses

- Low
- Medium
- High

Probability of occurrence
Conclusions: Climate Change and Infrastructure

• Long life assets having low autonomous adaptive capacity are vulnerable
• Impacts are location specific and are significant in long term, adaptation of long-term assets needs to begin early
• Environmental impacts assessment should assess impacts from climate change
• Technological measures, economic instruments (e.g. insurance) as well as development strategies are vital for adaptation
• Many infrastructure projects are also elements of adaptation strategy and impacts on these could be adverse to adaptation
• Causes of climate change impacts and solutions for adaptation are embedded within the development processes:
  – **Quality of development, i.e. development pathway matters**
  – **Mainstreaming Climate change actions accrue multiple dividends**
  – **Interests of projects need to be aligned with development and climate processes**
  – **Early adaptation for aligning financing and technical assessment of projects**
  – **Climate-friendly development should be rewarded rather than under-financed**
Scope for Future Work

- Establishing the parameters for the reverse link matrix and identification of the cost structure.
- Estimating risks associated with Extreme events
- More Sectoral case studies
- Identification of forcing variables and their critical (threshold) values for different sectors
- Linking of socio-economic / climate scenarios to critical parameters