Case Study: Konkan railway Corporation Limited

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Sustainable (& Reliable) Logistics and Climate Change Risks

- 47% of Projected Freight Demand will move on DFC's
- DFC's would therefore become critical to national freight movement
- DFC’s especially on Eastern and Western ghats could be more susceptible to weather vagaries, as even now the existing railway lines there experience operational difficulties during monsoons.
- What could happen, how to assess it, and what to do about it?
Climate Change Manifestation

- Climate is average weather of past 30 years at a place.
- Climate change (CC) manifests as weather of the day.
- Long-life assets are planned based on past weather mean and extremes.
- Weather mean and extremes may change under CC as shown, exposing the assets to altered risks - such as more number of rainy days, higher rain per day, altered locations for rainfall.
- Managing weather extremes is more critical for safe and economic operation of infrastructure assets.
- How much preventive design safety to include in a new railway project to climate proof it? How much for an existing asset? Each Safety Work comes with a price tag.
Uncertainty and Risks for I/S Assets

• Two types of risks
  • Implementing safety works for an event that does not eventually occur - Excessive safety? – wasted expenditure? – Type-1 error
  • Not planning for an extreme event which eventually occurs - Lower safety? – exposing passengers and goods to risks? – Type-2 error.

• CC uncertainty therefore creates
  • Risk of unwanted events happening
  • Costs required to avoid them (Preventive)
  • Costs to restore the system, in case events do occur (Palliative)
  • Costs of insurance against (un-covered) events

• How much Safety works are adequate to manage climate change risks?
• Can we, and should we, climate proof every railway line? What are the costs?
• Are there any instruments that could take care of un-covered risks?
• KRCL has already spent over Rs. 280 crore on additional safety works since 2001 (excluding development costs of Raksha Dhaga etc) and plans to invest another Rs. 340 crore in next 5 years, mainly to reduce risks of boulders falling and soil slippage. About 20% of annual engineering maintenance expenditure is due to weather related events.
• This is almost 15% (converted to constant prices) of its total construction cost of about Rs. 3500 crore.
Konkan Railway

- Connects two important ports of Mangalore and Mumbai
- First major infrastructure project to be taken on BOT basis
- Built on an extremely rugged terrain
  - 1998 Bridges (179-Major; 1819-minor) and 92 tunnels
  - Mountainous terrain with many rivers
  - Landslides a common problem due to excessive rainfall
  - First time IR built tunnels longer than 2.2 kms
  - More than 1000 cuttings in the track
- Exposed to excessive precipitation resulting in landslides - hampering train operations and safety

**Source:** KRCL
Salient Features of KRCL

**BRIDGES**
(TOTAL 2245 Nos)
Total Water Way Km. 25.403

**MAJOR BR.**
(No. 179)
(Water way length - 19.823 Km.)

**MINOR BR.**
(No. 1701)
(Water way length - 5.58 Km.)

**RUBs, ROBs & FOBs**
(No. 365)

**OTHERS**
(No. 85)
(KM. 61.734)

**TUNNELS**
(TOTAL 91 Nos)
Total Length Km. 84.496
(Total Curve Length Km. 23.484)

**CUTTINGS**
(TOTAL 564 Nos)
RN-349 & KW-215
Total Length Km. 226.71
(Length RN-125.65 & KW-101.06 Km.)

**BLASTLESS TRACK**
(No. 6)
(KM. 22.762)

**OTHERS**
(No. 85)
(KM. 61.734)

**Number of cuttings**

- 0 TO 4.9m: 51
- 5.0 TO 11.9m: 179
- 12.0 TO 14.9m: 79
- 15.0 TO 19.9m: 100
- 20.0 TO 24.9m: 81
- 25.0 TO 29.9m: 44
- 30.0 TO 34.9m: 18
- 35.0 TO 39.9m: 10
- 40.0 TO 50.0m: 2

**Height of cuttings**

- 0 TO 4.9m: 51
- 5.0 TO 11.9m: 179
- 12.0 TO 14.9m: 79
- 15.0 TO 19.9m: 100
- 20.0 TO 24.9m: 81
- 25.0 TO 29.9m: 44
- 30.0 TO 34.9m: 18
- 35.0 TO 39.9m: 10
- 40.0 TO 50.0m: 2

Total Water Way Km. 25.403
Total Length Km. 84.496
Total Length Km. 226.71
Accidents

Rescue operations in progress at Vaibhavwadi, the site of the Konkan Railway accident of June 22, 2003, in which more than 50 persons were killed.


The smashed coaches of the Matsyagandha Express after it hit a boulder and derailed at Amboli village on the Konkan Railway in Maharashtra's Raigad district on June 16, 2004.

http://www.hindu.com/fline/fl2114/stories/20040716001904200.htm
Accidents/Events

One of the boulders that derailed the Matsyagandha Express near Mahad in Maharashtra on June 16, 2004.


The collapse of retaining wall between Nivasar and Ratnagiri stations in Konkan Railway

Regional Temperature & Rainfall Projections: Snapshot

- Regional Projections: Annual Rainfall Increase in 2030s w.r.t 1970
  - Himalayan region: 5 to 13%
  - West coast: 6 to 8%; winter rainfall to decrease
  - East coast: 0.2% to 4.4%; Winter rainfall to decrease
  - North-Eastern Region 0.3% to 3%; Substantial winter rainfall decrease

<table>
<thead>
<tr>
<th>Region</th>
<th>Mean Annual Rainfall</th>
<th>SD</th>
<th>Mean Annual Temperature</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Himalayan</td>
<td>↑↑↑</td>
<td>↑↓↔</td>
<td>↑↑↑</td>
<td>↑↑↑</td>
</tr>
<tr>
<td>West Coast</td>
<td>↑↑↑</td>
<td>↑↓↑</td>
<td>↑↑↑</td>
<td>↑↔↔</td>
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<tr>
<td>East Coast</td>
<td>↑↓↑</td>
<td>↓↓↓</td>
<td>↑↑↑</td>
<td>↑↑↑</td>
</tr>
<tr>
<td>North East</td>
<td>↑↑↑</td>
<td>↑↑↑</td>
<td>↑↑↑</td>
<td>↑↑↑</td>
</tr>
</tbody>
</table>
Why is it a challenge?

- System thresholds
  - Climate system can react abruptly with limited warning signs before thresholds are crossed – flash floods (Stocker, 1999)
  - More than the averages, it is the extremes events are a cause of concern
    - Extreme Weather Event: An event that is rare at a particular place and time of year
    - “Rare” is defined as the highest or lowest 10% (IPCC, 2007)

- Unaccounted risks can wash away developmental benefits
  - Limited resources; Every resource unit has opportunity costs
  - Socio-economic already stressed with stressors like population growth, increased urbanization, resource use, and economic growth (MoEF, 2010; Sahoo & Dash, 2009; Straub, 2008; Garg, et al., 2007; Sathaye, et al., 2006)

- Infrastructure investment today will determine the development scenario & GHG emission trajectories in future
Weather and climate extremes are among the most serious challenges to society in coping with global warming.

- Weather-related insurance losses in the U.S. are increasing.
- Typical weather-related losses today are similar to those that resulted from the 9/11 attack (shown in gray at 2001 in the graph).
- About half of all economic losses are insured, so actual losses are roughly twice those shown on the graph.
Risk and Risk Management

- **Risk**: Potential for loss or damage to system
  - Arise out of uncertainties
  - Product of hazard and vulnerability (IPCC, 2007)

- **Risk management**: Systematic approach & practice of managing uncertainty to minimize potential harm and loss (UNISDR, 2009)
  - Risk assessment and analysis
  - Implementation of strategies and specific actions
    - Control
    - Reduce
    - Transfer risks
## Types of Risks

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical</strong></td>
<td>Exposure risks due to increase frequency and variability of climate variables.</td>
</tr>
<tr>
<td></td>
<td>Damage to tracks, railway infrastructure</td>
</tr>
<tr>
<td><strong>Regulatory</strong></td>
<td>Binding agreements; Influence of international policies</td>
</tr>
<tr>
<td></td>
<td>Change in fuel mix; Additional taxes</td>
</tr>
<tr>
<td><strong>Supply Chain</strong></td>
<td>Effect on essential supplies of petroleum, fertilizer, food grains</td>
</tr>
<tr>
<td></td>
<td>Annual Freight traffic to the tune of Rs. 297crore (2010-11)</td>
</tr>
<tr>
<td><strong>Product &amp; Technology</strong></td>
<td>Improvement in technologies to meet regulations</td>
</tr>
<tr>
<td></td>
<td>Existing assets may become redundant</td>
</tr>
</tbody>
</table>

**Source:** Carmianti (2010); Vespermann & Wittmer (2010); Lash & Wellington (2007); IRM, (2002)
## Some Impacts (Roads & Railways)

<table>
<thead>
<tr>
<th>CCC Parameter</th>
<th>Temperature, Precipitation, Extreme Events</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct Impacts</strong></td>
<td>Physical Damage</td>
</tr>
<tr>
<td></td>
<td>Boulder falling, land slides</td>
</tr>
<tr>
<td></td>
<td>Accidents, derailments, curtailed train operations</td>
</tr>
<tr>
<td></td>
<td>Joint Expansions, Rail cracks</td>
</tr>
<tr>
<td></td>
<td>Supply Chain Impacts</td>
</tr>
<tr>
<td><strong>Indirect Impacts</strong></td>
<td>Agriculture production and regional freight traffic</td>
</tr>
<tr>
<td></td>
<td>Enhanced cooling / Heating requirements</td>
</tr>
<tr>
<td></td>
<td>Modal shifts</td>
</tr>
<tr>
<td></td>
<td>Mitigation Pressures</td>
</tr>
<tr>
<td><strong>Risk Management</strong></td>
<td>Technology, e.g. Safety nets, reducing cuttings etc.</td>
</tr>
<tr>
<td></td>
<td>Better Communication</td>
</tr>
<tr>
<td></td>
<td>Insurance</td>
</tr>
</tbody>
</table>
Climate Change Adaptation & Costs

- Adjustment in systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
  - Reactive & Anticipatory
  - Planned & Autonomous
  - Complements & Supplements

- Adaptation, if taken up proactively, will reduce the damages from US$13 to 6 trillion in 2100 for the world (Agrawala, et al., 2009).

- World Development Report: Adaptation costs for developing world should be $75 billion/year over the period 2010 to 2050 (World Bank, 2010).

Analytical Framework
Integrated CC Assessment for Infrastructure

Global Emissions → Global Policy Regime & Agreements → CC resilient system & national GHG emissions

Uncertainty of Climate Change Variables

- T - Temperature
- S - Sea Level Rise
- P - Precipitation
- E - Extreme Events

Impacts due to CC

Risk = fn (Probability of occurrence, System resilience, Exposure)

Risk & uncertainty management

Development pathways & policies

Human & Natural Systems

Infra 1 → A

Infra 2 → A

Infra n → A

A - ADAPTATION

Source: Adapted from IPCC (2007)
Risk Management Framework

- Infrastructure
  - Identify CCC Parameters
  - Future Projection for CCC parameters & related uncertainties
- System Conditions
- Sustainable Development Indicators
- Ensure Regular Monitoring
  - Is the Infrastructure resilient & sustainable in long-run?
    - Yes
    - No
- Impact Assessment & Damage Function Estimation
  - Forward Impact
  - Reverse Impact
- Risk Management
- Impact Management
  - Preventive
  - Palliative
- Adaptation

Feedback: Policy / Market induced enforcements for more climate change resilient infrastructure
### Reverse Impact Matrix

<table>
<thead>
<tr>
<th>Forcing Variables \ Dépendent Variables</th>
<th>Environmental Variables</th>
<th>Project Components</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Variables</strong></td>
<td>Quadrant 2: Environmental impact inter-linkages</td>
<td>Quadrant 3: Reverse Impact (impacts of environment on project)</td>
</tr>
<tr>
<td><strong>Project Components</strong></td>
<td>Quadrant 1: Forward Impact (impacts of project on environment)</td>
<td>Quadrant 4: Project’s impact on other projects</td>
</tr>
</tbody>
</table>

**Source:** Kapshe, et al. (2003)
## Climate Impact Matrix

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Environmental Variables</th>
<th>Project Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forcing Variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Rainfall</td>
<td>--</td>
<td>L</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Extreme events</td>
<td>--</td>
<td>L</td>
</tr>
<tr>
<td>Water logging</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Vegetation growth</td>
<td>L</td>
<td>--</td>
</tr>
<tr>
<td>Land slide</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Safety/Efficiency</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Maintenance</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Traffic volume</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

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

### Forcing Variables
- Temperature
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### Environmental Variables
- Temperature
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### Project Components
- Temperature
- Rainfall
- Sea level rise
- Extreme events
- Water logging
- Vegetation growth
- Land slide
- Safety/Efficiency
- Maintenance
- Traffic volume

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Framework for Designing Insurance Packages for CC Impacts

- Impact matrix creation and analysis
- Identify critical climate change (CC) parameters
- Estimate damage function
  - Historical relationship between economic damages and CC impacts
  - Adjust for intensity and frequency of climatic impacts
- Get future projections for CC parameters
- Estimate economic losses in future and their probability distribution
- Adjust for discontinuities, if likely to be considerable
- Analyze alternatives to manage these losses and associated risks, and likely cost of these alternative options
- Annual insurance package
  - Annualized highest loss scenario (from Insurance company’s perspective)
  - Annualized lowest damage scenario (asset owner’s perspective)
  - Risk weighted average
Risk Estimation and Valuation

Economic Loss (EL) = Infrastructure Loss (Stock) + Operating Loss (Flow)

\[ EL = f (SDV_i, SCV_j, CCV_k) + g (OL_l) \]

SDV: Sustainable Development Variables
SCV: System Condition Variables
CCV: Climate Change Variables
OL: Operating loss

\( i = \) Forest cover, new habitats near KR route etc.
\( j = \) Track maintenance level, cuttings, new technology (wire-nets, warning systems) etc.
\( k = \) Extreme Rainfall, new rainfall locations etc.
\( l = \) Traffic lost, Restoration costs etc.

Vulnerability of KRCL to climate change will be captured by \( SDV_i, SCV_j, CCV_k \)

Adaptation will be captured through \( SDV_i, SCV_j \)

Incidence of loss could happen when, \( CCV_k \geq T_k \) (Critical threshold for variable k)
Damage Function Estimation

Expected value of damages or Economic Loss (EL) of a climate change related event could be given as:

\[ E[EL] = \text{function} \left\{ \sum_m \sum_n (p_{mn}) (EV) \right\} \]

Where,
- \( m \) = Location where event occurs, such as land slide or boulder falling location;
- \( n \) = Weather incident such as rainfall > 200 mm in 24 hours,
- \( p \) = probability of event for a given \( m \) and \( n \) under a projected climate change scenario \( C \);
- \( EV \) = economic value of event \( n \) occurring at location \( m \). This would capture all the preventive and palliative expenditure done at \( mn \).
- \( C \) = Projected climate change scenarios (BAU, A1B, SD)

Damage attributable to climate change = \( E[EL (A1B)] - E[EL (BAU)] \)

Economic Savings in a SD scenario = \( E[EL (A1B)] - E[EL (SD)] \)
Boulder falling & Landslides with Traffic Interruptions

Increase
Total cases of Boulder falling & Landslides
Boulder Falling & Soil Slips

Large number of cases in initial years

Gradual decline

Increase in 2003-04

Fall in Maintenance E.

Drastic decline
## Maintenance Expenditures

<table>
<thead>
<tr>
<th>Year</th>
<th>Bridges &amp; Tunnels</th>
<th>Plant &amp; Equipment</th>
<th>Permanent Way</th>
<th>Stations &amp; other Buildings</th>
<th>Rolling Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995-96</td>
<td>806,161</td>
<td>1,285,958</td>
<td>14,472,652</td>
<td>3,232,102</td>
<td>134,714</td>
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<tr>
<td>1996</td>
<td>2,685,235</td>
<td>1,450,971</td>
<td>16,464,760</td>
<td>3,235,914</td>
<td>781,719</td>
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<tr>
<td>1997</td>
<td>4,253,052</td>
<td>18,110,044</td>
<td>53,751,451</td>
<td>1,759,736</td>
<td>4,990,139</td>
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<tr>
<td>2003-04</td>
<td>64,192,860</td>
<td>75,698,749</td>
<td>411,219,788</td>
<td>38,059,646</td>
<td>23,909,770</td>
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<tr>
<td>2004-05</td>
<td>24,259,305</td>
<td>81,661,809</td>
<td>480,899,859</td>
<td>65,662,078</td>
<td>18,158,138</td>
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<tr>
<td>2005-06</td>
<td>13,957,193</td>
<td>95,332,205</td>
<td>263,620,310</td>
<td>55,855,804</td>
<td>22,632,987</td>
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<tr>
<td>2006</td>
<td>22,232,987</td>
<td>141,688,637</td>
<td>332,181,503</td>
<td>85,824,351</td>
<td>42,514,651</td>
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<tr>
<td>2010</td>
<td>24,707,595</td>
<td>106,687,318</td>
<td>279,731,580</td>
<td>65,470,209</td>
<td>53,849,548</td>
</tr>
</tbody>
</table>

**Over base year 1997-98 (Train operations began in 1998)**

- Bridges & Tunnels: 6 Times
- Plant & Equipment: 6 Times
- Permanent Way: 5 Times
- Stations & other Buildings: 37 Times
- Rolling Stock: 10 Times

### Decrease in YoY maintenance spending
## Accident Statistics

<table>
<thead>
<tr>
<th>Cause</th>
<th>Proportion</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural</td>
<td>61.54%</td>
<td>16</td>
</tr>
<tr>
<td>Material Failure</td>
<td>11.54%</td>
<td>3</td>
</tr>
<tr>
<td>Failure of Railway staff</td>
<td>15.38%</td>
<td>4</td>
</tr>
<tr>
<td>Others</td>
<td>11.54%</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>#</th>
</tr>
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<tbody>
<tr>
<td>1999-00</td>
<td>4</td>
</tr>
<tr>
<td>2000-01</td>
<td>9</td>
</tr>
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<td>2001-02</td>
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<td>2002-03</td>
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<td>2</td>
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<td>2005-06</td>
<td>1</td>
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<tr>
<td>2006-07</td>
<td>1</td>
</tr>
<tr>
<td>2007-08</td>
<td>1</td>
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<tr>
<td>2010-11</td>
<td>2</td>
</tr>
</tbody>
</table>

### Damage in Rs Lakhs
Rainfall Pattern

Spatial pattern of projected seasonal precipitation change (mm) for 2050 relative to 1990s
Value

High: 0.000716551
Low: -3.91527e-017

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Mangaon and PRECIS Grid

Location: Mangaon (PRECIS Grid 39-39)

Legend:
- Railway Station
- Rainfall monitoring locations (Source: KR-HQ)
- Railway Track (Konkan Railways)
- PRECIS Grids Covering Konkan Railway Route
- Other PRECIS Grids in the framework
- State Boundaries/India

Mangaon Station (June 01, 2000 to October 07, 2009)

Scenario: BL

Source: NATCOM data

Scenario: A2

Source: NATCOM data

Scenario: B2

Source: NATCOM data
Current Geo-tech Safety Works

- **Boulder Netting**
  A Rock fall protective measure
  Quantity Executed (MT): 44.55
  Total Cost (\` Crore): 37.16

- **Shot-Creting**
  To arrest the boulder falls and loose rocks from falling in tunnels and cuttings
  Quantity Executed (sqm): 11255
  Total Cost (\` Crore): 68.63
Current Geo-tech Safety Works

- **Rock Bolting**
  
  To anchor loose boulders to the parent rock and prevent them from falling in tunnels and cuttings
  
  Quantity Executed (MT): 1699.84

- **Micro Piling**
  
  A geo-technical engineering solution to prevent slope failure in soil cuttings
  
  Quantity Executed (MT): 44.55
  Total Cost (Crore): 37.16

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Current Geo-tech Safety Works

- **Soil Nailing**
  A geo-technical engineering solutions to strengthen the soil slope and avoids its failure
  - Quantity Executed (MT): 44.55
  - Total Cost (\` Crore): 37.16

- **Vetiver Plantation**
  Vetiver grass grown on the slopes to form a hedge which acts like a barrier for soil loss
  - Quantity Executed (rmt): 56944
  - Total Cost (\` Crore): 12.2
Current Geo-tech Safety Works

- Flattening of slopes
- Construction of Toe walls
- Ballast retainer walls
- Lining of catch water drains
Technology currently in use

- **RakshaKavach - Anti-Collision Device Network**

  A Network of ‘on-board’ (Locomotive and Guard) and ‘track-side’ (Station, Level Crossing, Locoshed, Repeater and Sensor-based) ACDs that work on the principle of ‘Distributed Control Systems’
Analysis and Conclusions
Stylized interaction of relevant CCV with SDV (Under BAU)

Stylized variable levels (IA2)
- CCV (rain \(\geq 200\) mm/day)
- SDV (forest cover)
- SDV (technological inputs)

System resilience:
- With technological inputs
- Without technological inputs

System resilience threshold level to withstand adverse impacts

Graph showing trends from 2000 to 2100.

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Stylized interaction of relevant CCV with SDV (Under SD)

Stylized Variable Levels (IB1)

Adverse CCV (rain >= 200 mm/day)

SDV (technological inputs)

System resilience threshold level to withstand adverse impacts

System resilience with technological inputs

SDV (forest cover)
Damage Cost: Integrating SC, CCV & SDV Impacts

- Long-life assets commissioned now will have higher failure rates after a century when they become old.
- Climate change shall also exacerbate in later part of the 21st century. Therefore, impact probability and costs on the infrastructure would increase significantly in later years.
Economic Loss & Probability of Occurrence

- Reference scenario (RS)
- RS with adverse CCV and strongly favourable SDV
- RS with adverse CCV (SDV not considered)
- RS with adverse CCV and adverse SDV
Risk Management Strategies: Short Term

- Technological solutions (risk mitigation strategy)
  - Cutting, tunnels - various civil works
  - Enhanced repair and maintenance expenditure (around 20%)
  - Gadgets (Raksha dhaga etc)
  - Costs: US$ 110 million (almost nil failures?), US$ 15 million (failures but warn adequately to avoid accidents)

- Train operations (risk avoidance strategy)
  - Train cancellations and diversions
  - Speed restrictions

- Institutional (risk transfer)
  - Disaster management and accident relief strengthening (risk retention)
  - Accident insurance for lives lost/injured (risk transfer)
Risk Management Strategies: Long Term

- **Technological solutions (risk mitigation)**
  - May play less prominent role due to technological lock-ins
  - Old systems, strong CC – higher impacts likely
  - Utilize opportunities in short to medium-terms to strengthen the system, e.g. Cutting flattening, anti collision devices

- **Developmental paradigms (risk mitigation)**
  - Forest cover and settlement management

- **Institutional (risk transfer)**
  - Access adaptation funds
  - Insurance for assets
  - Insurance against extreme climatic events
Thanks
Insurance on Indian Railways

- System-wide insurance cover existing on Indian Railways
- Only death or injuries due to accidents insured
  - US$ 9000 in the case of death and permanent disability
  - Up to US$ 2000 in the event of injuries
- Annual premium US$ 9 million
- No outside asset insurance cover
  - Damages worth US$ 45 million in 2004-05 due to all consequential accidents
  - Reduced to US$ 10 million in 2005-06
Climate Change Impacts and Insurance

- Assessment of impacts parameters and costs
- Establishment of monitoring system
- Reliable regional climate projections
- Identification of adaptation responses, including technologies.
- Developing insurance market for infrastructures
Cost of Climate Change

- Cost of accidents, reduced train operation & derailment restoration etc: Rs 40 Crore (rough estimation)
- Preventive Geo-tech safety works already done (1999-2012) : Rs. 277.84 Crores (actuals)
- Planned Permanent measures in cutting & tunnels for next 5 years (2011-12 to 2015-16) : Rs. 340 Crores
- Total cost : Rs. 637.84 Crores
- Cost of construction of Konkan Railway : Rs. 3500 Crores
# Abstract of Geo-Tech Safety Works

Done in the Year 2012 - 13 (1st April 2012 TO 31st July 2012)

<table>
<thead>
<tr>
<th>Sr.NO</th>
<th>Item of Work</th>
<th>Unit</th>
<th>Quantity Executed</th>
<th>Cost of work done (` in Crores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earthwork for flattening of slope &amp; creation of berms &amp; Refixing of HSBN</td>
<td>Cum</td>
<td>245000</td>
<td>6.25</td>
</tr>
<tr>
<td>2</td>
<td>RCC Retaining wall and Gabion wall.</td>
<td>Cum</td>
<td>3874.20</td>
<td>2.42</td>
</tr>
<tr>
<td>3</td>
<td>a) Shotcreting</td>
<td>Sqm</td>
<td>11255</td>
<td>1.97</td>
</tr>
<tr>
<td></td>
<td>b) Rock Bolting</td>
<td>MT</td>
<td>44.55</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Pitching</td>
<td>Cum</td>
<td>535.54</td>
<td>0.01</td>
</tr>
<tr>
<td>5</td>
<td>Catchwater drain (CWD) lining</td>
<td>Cum</td>
<td>1134.32</td>
<td>0.67</td>
</tr>
<tr>
<td>6</td>
<td>Soil nailing</td>
<td>Rmt</td>
<td>5239.00</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>12.04</strong></td>
<td></td>
</tr>
</tbody>
</table>


The cost abstract of yearwise planning of permanent measures

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flattening of slopes in cuttings, retaining wall, lining of catch water drains and side drains, etc.</td>
<td>40</td>
<td>60</td>
<td>60</td>
<td>70</td>
<td>70</td>
<td>300</td>
</tr>
<tr>
<td>Rock bolting and shotcreting in Tunnels.</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>340</td>
</tr>
</tbody>
</table>

All figures are in `crores
ABSTRACT OF GEO-TECH SAFETY WORKS DONE IN CUTTINGS/TUNNELS ON KONKAN RAILWAY FROM 1999 TO 2012 (upto 31/07/12)

<table>
<thead>
<tr>
<th>Sr.NO</th>
<th>Item of work</th>
<th>Quantity</th>
<th>Cost of work done (\text{in Crores})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earthwork for flattening of slope &amp; creation of berms &amp; Refixing of HSBN</td>
<td>86.8 Million Cum</td>
<td>101.73</td>
</tr>
<tr>
<td>2</td>
<td>RCC Retaining Wall</td>
<td>23769.85 Cum</td>
<td>31.92</td>
</tr>
<tr>
<td>3</td>
<td>Gabion Wall</td>
<td>38234 Cum</td>
<td>2.79</td>
</tr>
<tr>
<td>4</td>
<td>Micropiling</td>
<td>56944 Rmt</td>
<td>12.20</td>
</tr>
<tr>
<td>5</td>
<td>Grouting</td>
<td>80096 Bags</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Catchwater drain (CWD) lining</td>
<td>31951 Cum</td>
<td>11.14</td>
</tr>
<tr>
<td>7</td>
<td>Pitching</td>
<td>26510 Sqm</td>
<td>0.31</td>
</tr>
<tr>
<td>8</td>
<td>Shotcreting</td>
<td>657053 Sqm</td>
<td>68.63</td>
</tr>
<tr>
<td>9</td>
<td>Rock Bolting</td>
<td>1699.84 MT</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Soil nailing</td>
<td>42358 Rmt</td>
<td>4.04</td>
</tr>
<tr>
<td>11</td>
<td>Geomatting</td>
<td>148000 Sqm</td>
<td>0.77</td>
</tr>
<tr>
<td>12</td>
<td>Loosescaling</td>
<td>23701 Cum</td>
<td>1.24</td>
</tr>
<tr>
<td>13</td>
<td>Bouldernetting</td>
<td>1216000 Sqm</td>
<td>37.16</td>
</tr>
<tr>
<td>14</td>
<td>Sand Dampners</td>
<td>883763 Bags</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Laterite stone masonry</td>
<td>950 Cum</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Rakha Dhaga</td>
<td>807 Nos</td>
<td>0.48</td>
</tr>
<tr>
<td>16</td>
<td>Catchfencing</td>
<td>5659 Rmt</td>
<td>1.93</td>
</tr>
<tr>
<td>17</td>
<td>Vetiver Grass Plantation</td>
<td>79.12 Lac. Sapling</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>TOTAL -</td>
<td></td>
<td>277.84</td>
</tr>
</tbody>
</table>
Abstract of Year wise expenditure

<table>
<thead>
<tr>
<th>Year</th>
<th>Approximate Expenditure (` In Crores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999-2000</td>
<td>3.45</td>
</tr>
<tr>
<td>2000-01</td>
<td>6.63</td>
</tr>
<tr>
<td>2001-02</td>
<td>8.35</td>
</tr>
<tr>
<td>2002-03</td>
<td>5.20</td>
</tr>
<tr>
<td>2003-04</td>
<td>23.68</td>
</tr>
<tr>
<td>2004-05</td>
<td>33.64</td>
</tr>
<tr>
<td>2005-06</td>
<td>21.60</td>
</tr>
<tr>
<td>2006-07</td>
<td>29.96</td>
</tr>
<tr>
<td>2007-08</td>
<td>35.16</td>
</tr>
<tr>
<td>2008-09</td>
<td>32.48</td>
</tr>
<tr>
<td>2009-10</td>
<td>26.39</td>
</tr>
<tr>
<td>2010-11</td>
<td>18.80</td>
</tr>
<tr>
<td>2011-12</td>
<td>20.46</td>
</tr>
<tr>
<td>2012-13 (As on 31/07/12)</td>
<td>12.04</td>
</tr>
<tr>
<td>TOTAL -</td>
<td>277.84</td>
</tr>
</tbody>
</table>
## Short Term solutions

<table>
<thead>
<tr>
<th>Climatic Parameter</th>
<th>Impact Parameter</th>
<th>Intervening Parameter</th>
<th>Impact on KRC</th>
<th>Short Term Solutions</th>
</tr>
</thead>
</table>
| Temperature Increase | High Evaporation rate  | Stability and strength of the building materials. | 20% of repair and maintenance expenses are due to climatic reasons          | 1) Increased budgetary allocations for repair and maintenance  
2) Increase the frequency of maintenance |
|                      |                        |                                        |                                                                              |                                                                                      |
| Surface and Ground Water Loss | Crop production affected | Agricultural freight traffic | Konkan Railway will have to adjust its fares in order to balance agricultural freight and passengers |                                                                                      |
| Need for Air conditioning | Passenger traffic may shift to air conditioned staff | Affects efficiency, carrying capacity and composition. | 1) Will need to increase fares for account for the decreased efficiency in using fuel  
2) Will need to improve utilization of the existing railway lines in order to maintain carrying capacity i.e. more trains on the same route  
3) Alter distribution of AC and non-Ac coaches |                                                                                      |
# Short term solutions

<table>
<thead>
<tr>
<th>Climatic Parameter</th>
<th>Impact Parameter</th>
<th>Intervening Parameter</th>
<th>Impact on KRC</th>
<th>Short Term Solutions</th>
</tr>
</thead>
</table>
| Rainfall Increase  | Ground and Surface water level change | Flooding and Water Erosion reduces quality of land cover Logging | 1) Buildings affected and structural damages  
2) Increased maintenance and other related costs  
3) Line might be closed for increased duration during monsoons | 1) Reduction in average speed during the monsoons  
2) Using high and medium strength steel nets for slope stabilization  
3) Speed reduction |
|                    |                  |                       |               |                     |
| Improve Rainfall availability in the region | Agricultural production | Changes in agricultural freight tariff | The freight rates will need to be revised |                     |
| Humidity increase  | Uncomfortable climatic conditions, Vegetation growth on the track | Passenger traffic affected, increased maintenance cost | Cost of maintenance will increase and more people need to be hired for de-weeding the tracks. |                     |
## Short term solutions

<table>
<thead>
<tr>
<th>Climatic Parameter</th>
<th>Impact Parameter</th>
<th>Intervening Parameter</th>
<th>Impact on KRC</th>
<th>Short term Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level Change</td>
<td>Land Erosion</td>
<td>Tracks tunnels and bridges may be affected</td>
<td>Increased maintenance</td>
<td>1) Increased long term spending will be required for rock bolting.</td>
</tr>
<tr>
<td>Flooding</td>
<td>Land Stability and land slides</td>
<td>Damage to infrastructure. Reconstruction and Relocation</td>
<td>Improve drainage facilities on the tracks</td>
<td></td>
</tr>
<tr>
<td>Water logging</td>
<td></td>
<td></td>
<td>Delays, Risk Increase</td>
<td></td>
</tr>
<tr>
<td>Extreme Events</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>
<td>Long term solutions like insurance are needed</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>
<td>Long term solutions like risk transfer i.e. insurance are needed</td>
</tr>
</tbody>
</table>