Climate Change Impacts and Adaptation Issues for Infrastructure Assets

Manmohan Kapshe
Maulana Azad National Institute of Technology, Bhopal, India

P.R. Shukla
Indian Institute of Management, Ahmedabad, India

Amit Garg
Risø National Laboratory, Roskilde, Denmark

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

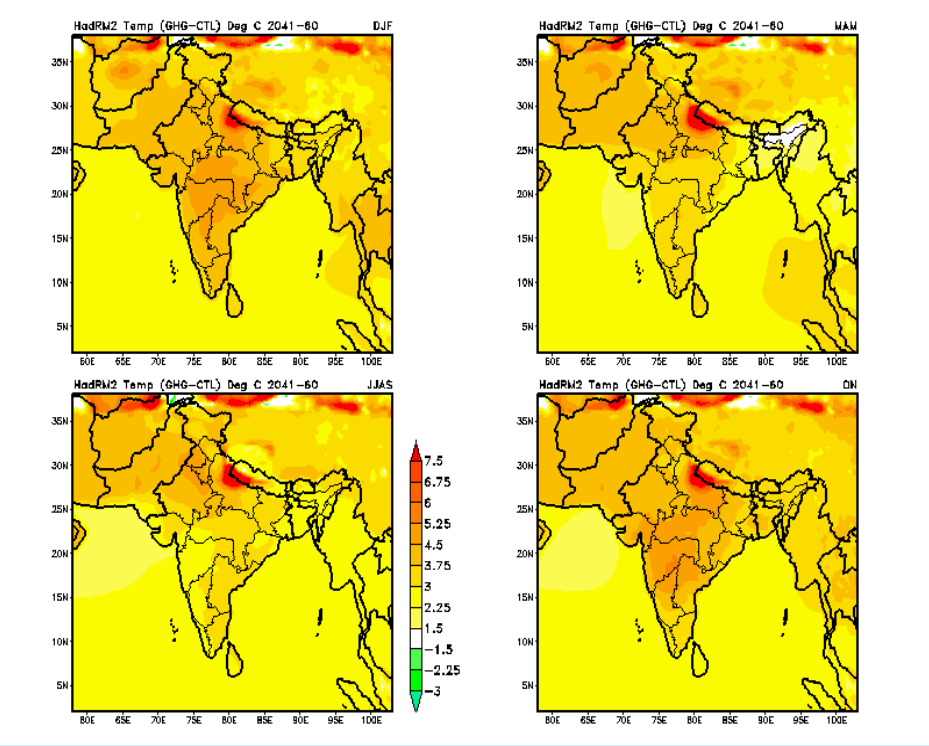
Categories of Climate Impacts

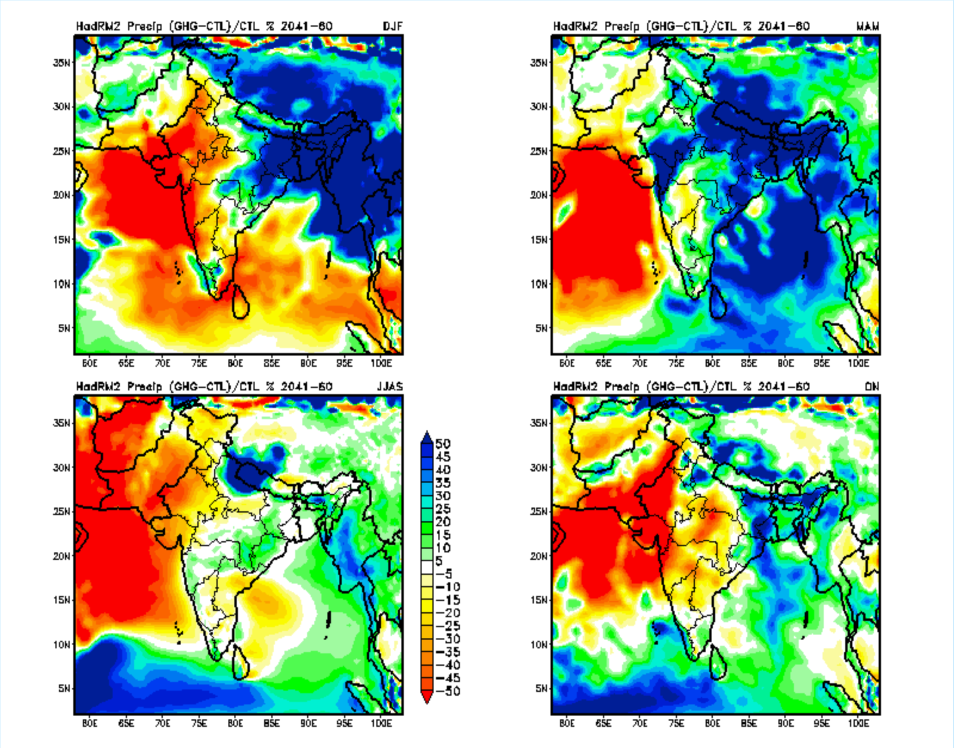
- Environmental quality (e.g., Air pollution, water logging or salinity increase, etc.)
- Linkage systems (e.g., threats to water supply or storm effects on power supply, increased competition for critical inputs)
- Social infrastructure (e.g., changed energy/water/health requirements, heat island effects, 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

	Humidity	Water Availability	Sedimentation	Flooding /Water Logging	Vegetation	Mangroves	Marine Life	Structural Stability	Land Slide	Land Erosion
Temperature Rise	↓	↓		↓	↓ ↑	↓	↓ ↑			
Precipitation Increase	↑	↑	↓ ↑	↑	↑	↑		↓	↑	↑
Sea Level Rise			↓ ↑	↑	↓	↓ ↑	↓ ↑	↓	↑	↑
Increase in Extreme Events				↑				↓	↑	

Assessment Framework:

Incorporating Development and Climate Change paradigm for impact assessment

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.)

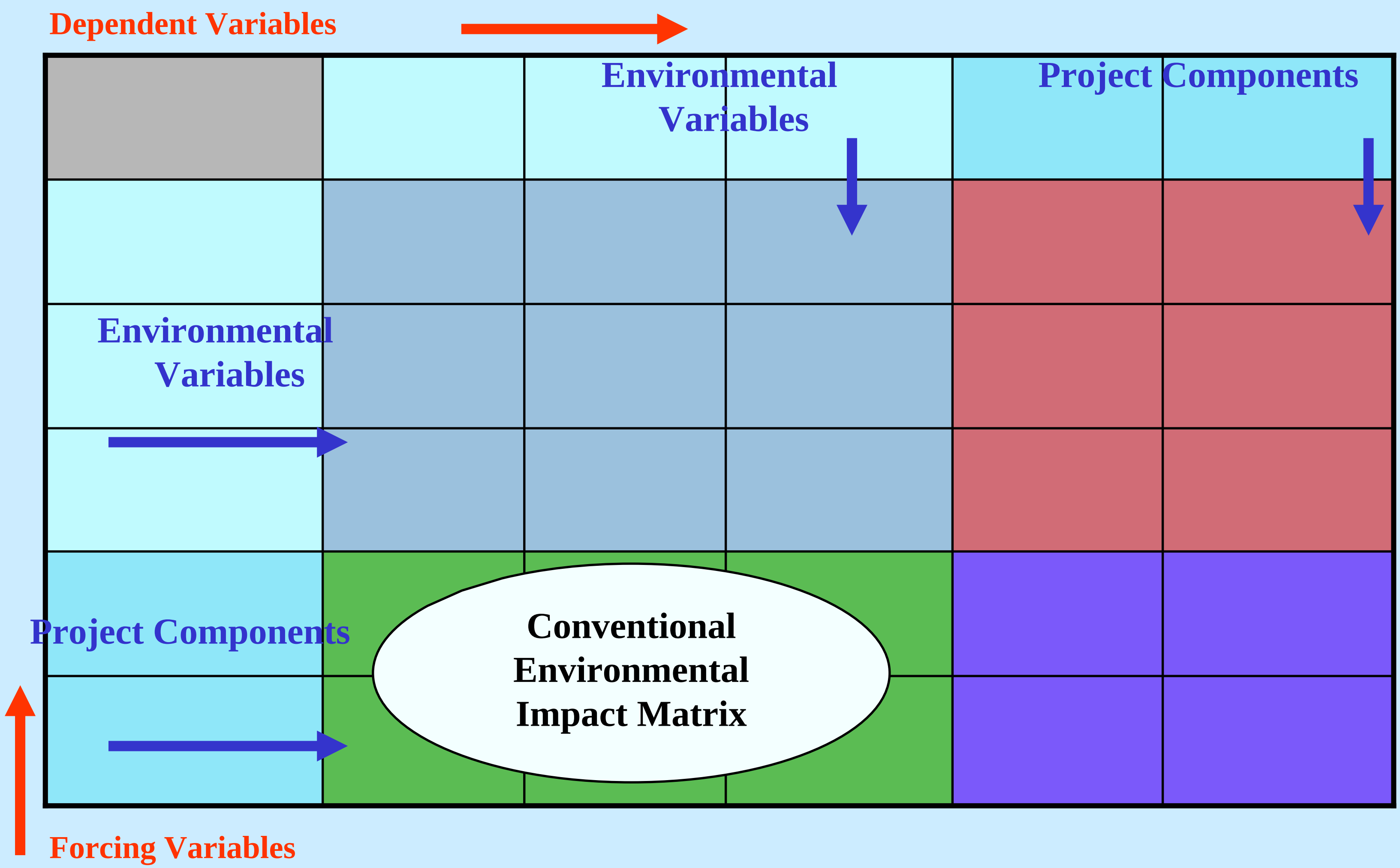
CCV = Projections for relevant Climate Change Variables

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

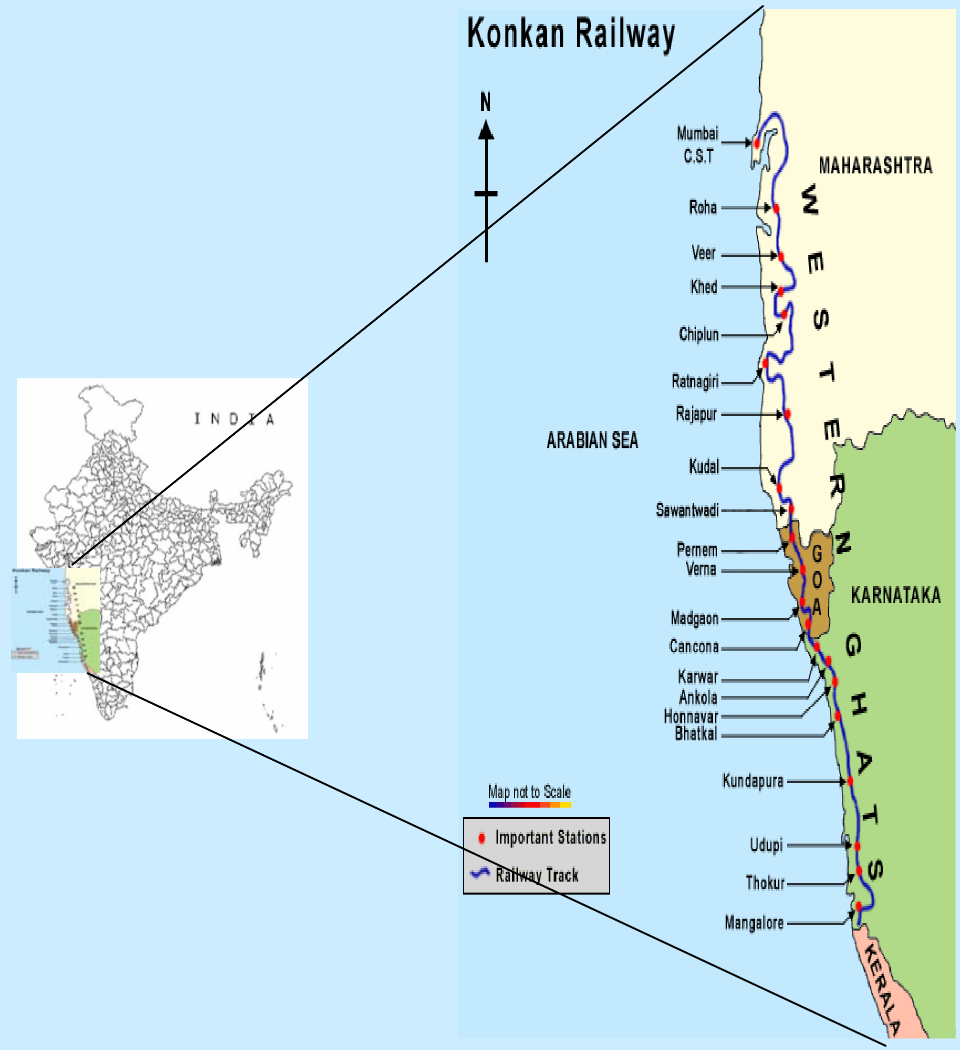
k = Life, maintenance levels, usage patterns, soil type, etc.

Reverse Impact Matrix

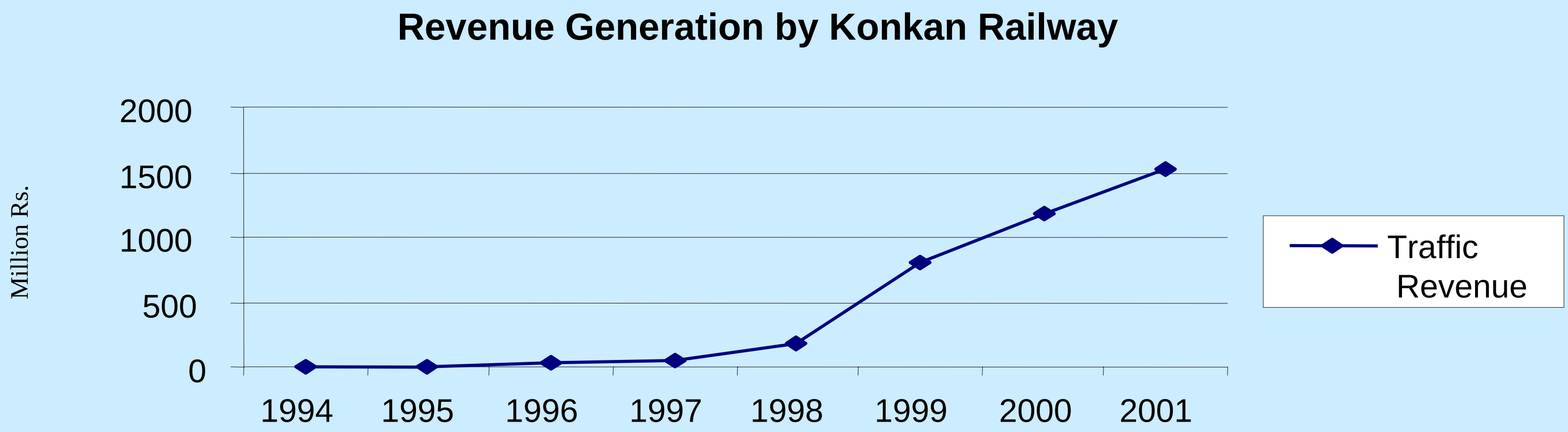


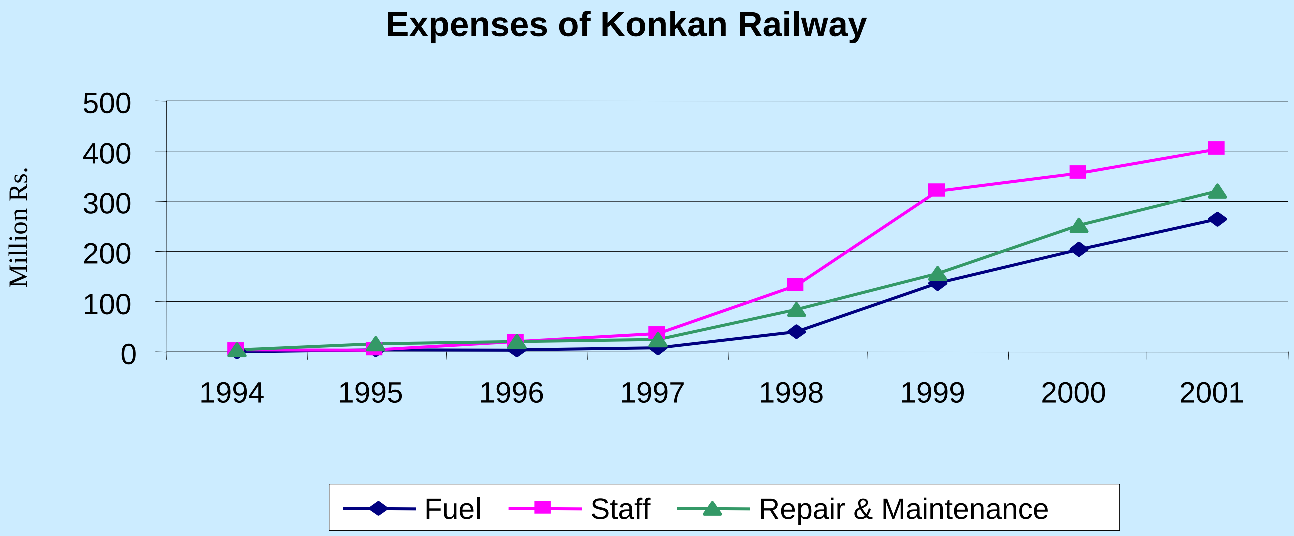
Case Study: Konkan Railway

- 760 Kms along Western coastal ghats
- $745 million project
- Considered and 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.



Konkan Railway: Revenues and Expenses



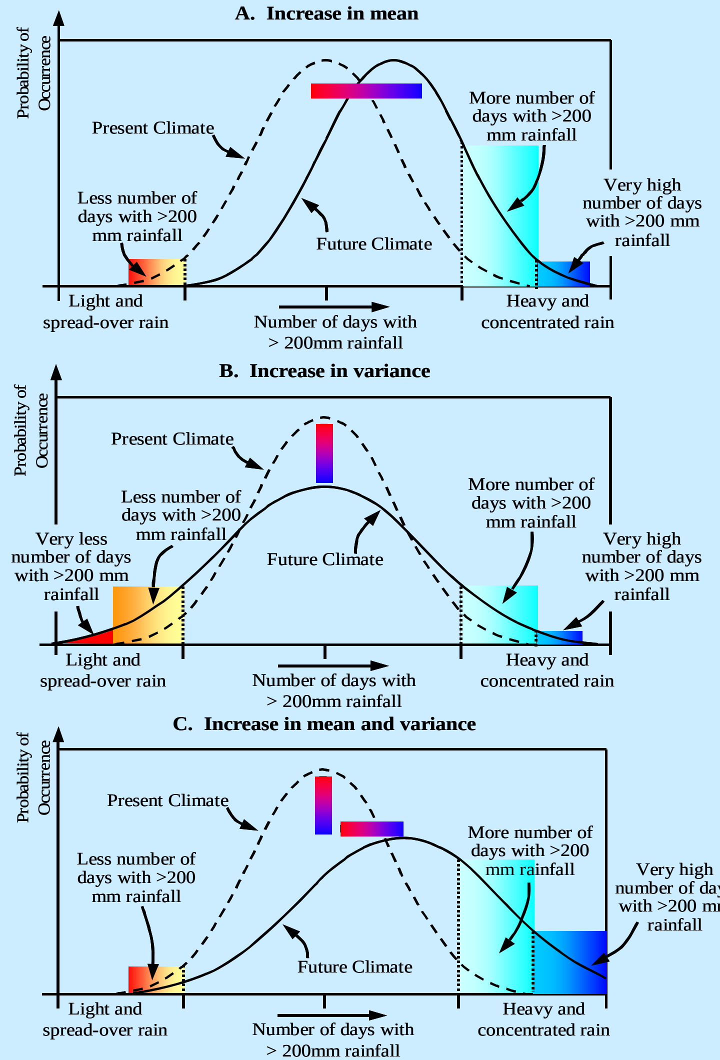


Climate Change: A case of Konkan Railway

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

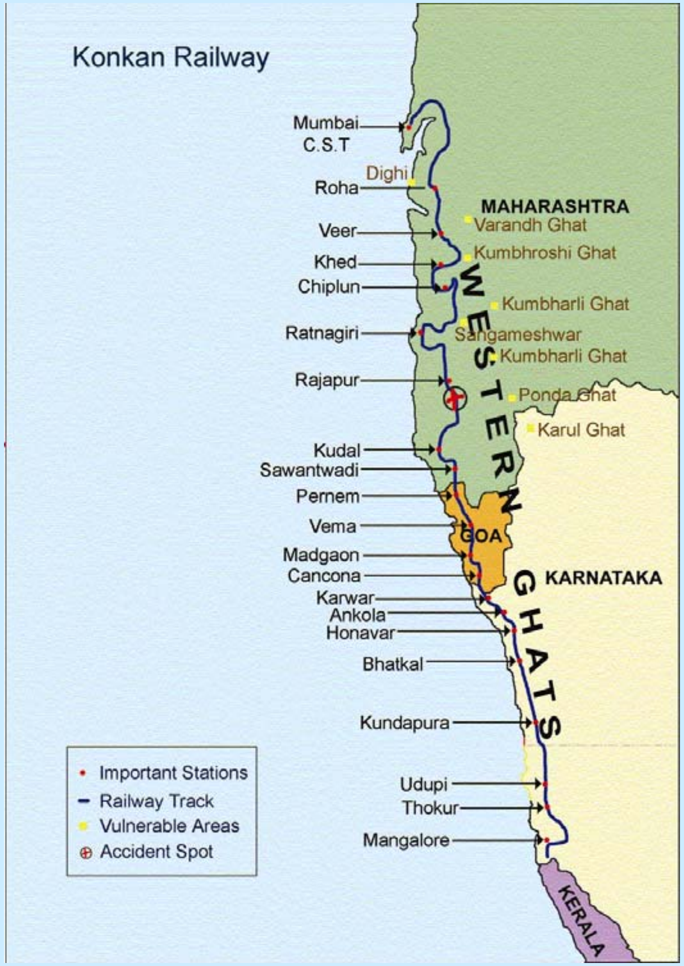
Application of Reverse Impact Matrix to Konkan Railway

	Forcing Variables \ Dependent variables	Temperature (Environmental Variables)	Rainfall (Environmental Variables)	Sea level rise (Environmental Variables)	Extreme events (Environmental Variables)	Water logging (Environmental Variables)	Vegetation growth (Environmental Variables)	Land slide (Environmental Variables)	Safety/Efficiency (Project Components)	Maintenance (Project Components)	Traffic volume (Project Components)
Environmental Variables	Temperature		L	M	L	--	L	--	--	--	L
Environmental Variables	Rainfall	L		--	M	M	M	H	L	L	M
Environmental Variables	Sea level rise	--	--		--	M	L	M	L	--	L
Environmental Variables	Extreme events	--	L	--		M	--	M	L	--	M
Environmental Variables	Water logging	--	--	--	--		--	L	L	--	M
Environmental Variables	Vegetation growth	L	L	--	--	--		L	--	L	--
Environmental Variables	Land slide	--	--	--	--	M	L		M	L	H
Project Components	Safety/Efficiency	--	--	--	--	L	--	L		M	M
Project Components	Maintenance	--	--	--	--	M	L	H	H		M
Project Components	Traffic volume	--	--	--	--	--	--	--	L	M	



Konkan Railway: Impacts and Adaptation

- 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



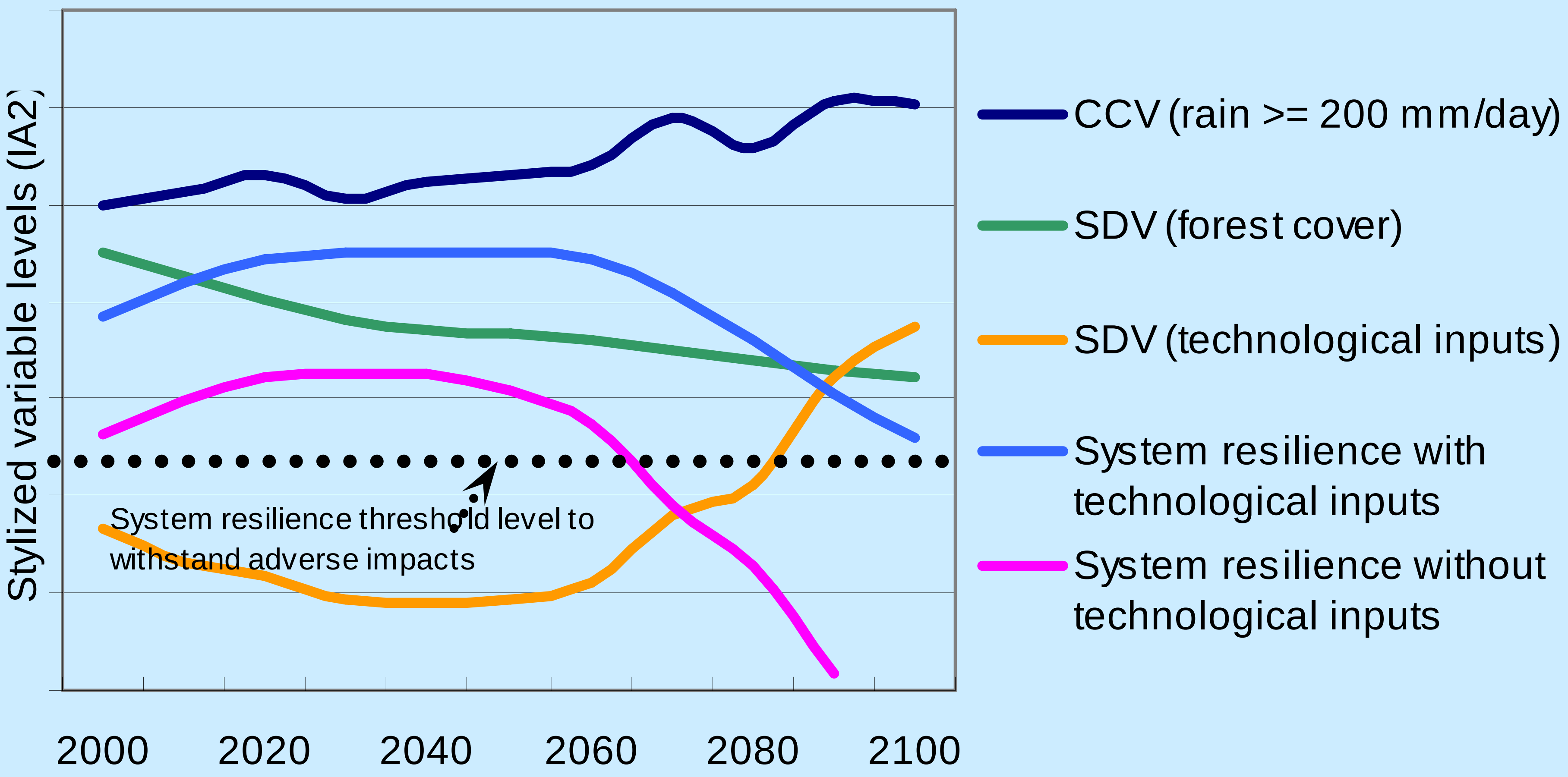
Key Impact parameters for Konkan Railway

- 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

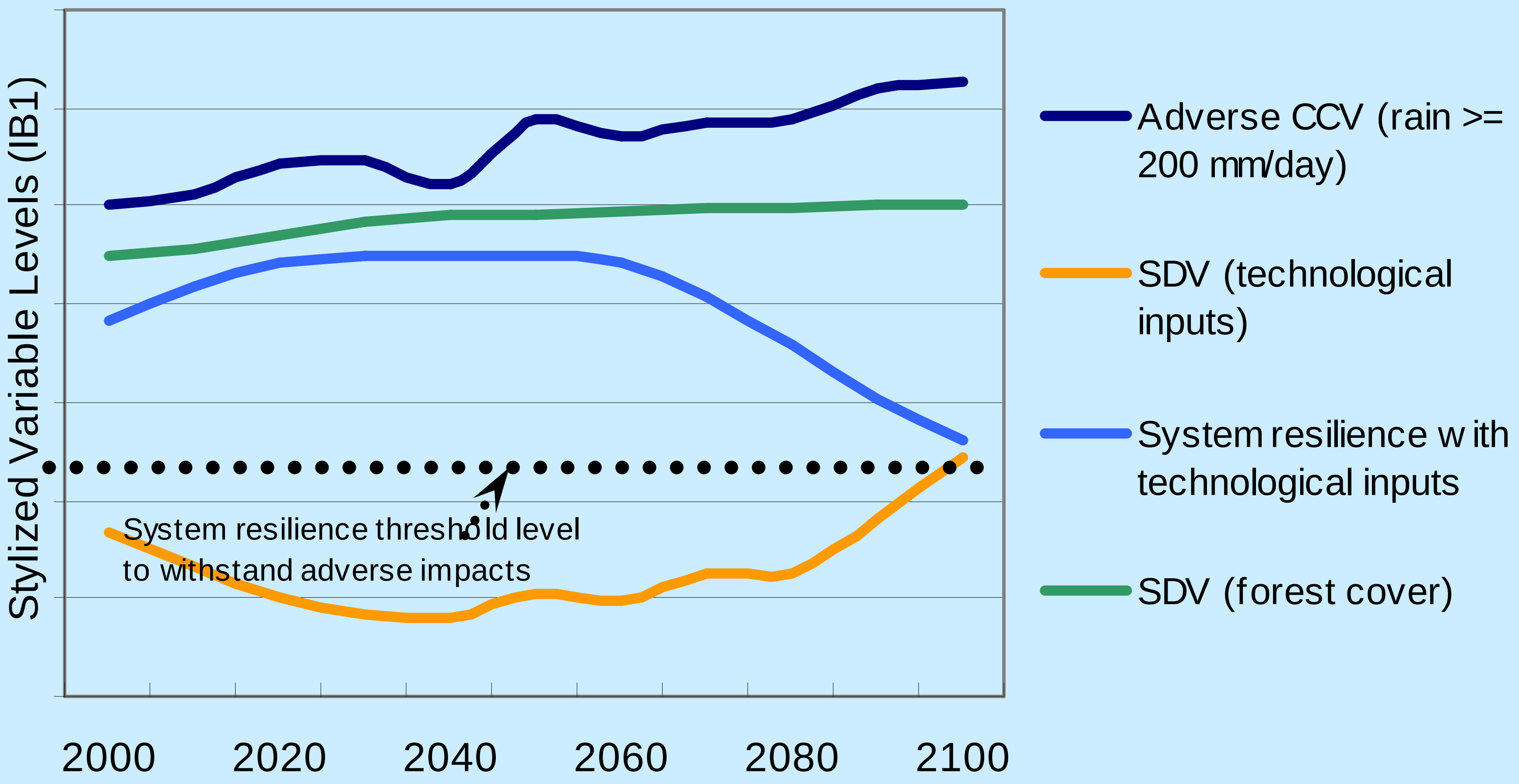
Scenario	Key Drivers	Implications on critical parameters of the scenarios and modeling analysis
IA2: Reference scenario	GDP growth, Energy efficiency, Non-fossil fuels vs. fossil fuels, Oil consumption, Technological change, Movement on the fuel ladder	Sectoral demands (↑↓), investment limits (↑↓), fuel supply (↑↓), Forest cover (↓), Efficiencies of technologies using oil and gas (↑)
IB1: Sustainable Development scenario	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	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 (↑)

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



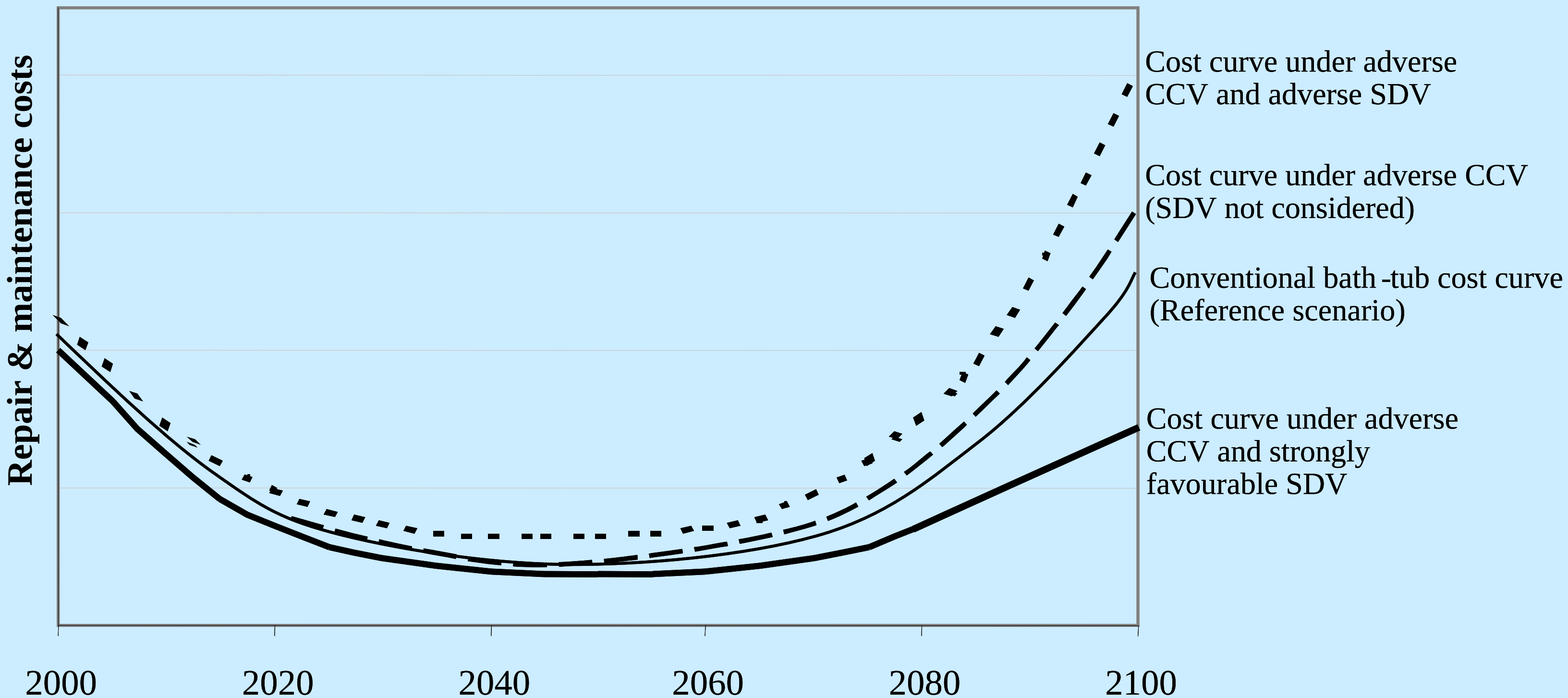
Rainfall variable projections akin to IPCC A2 from *Rupa Kumar et al., 2003*
Forest cover in the year 2000 for concerned districts from *Status of Forest Report, 2002*

Stylized interaction of relevant CCV with SDV to keep the impacts within system resilience levels for the Konkan Railway under IB1 (Sustainable development)



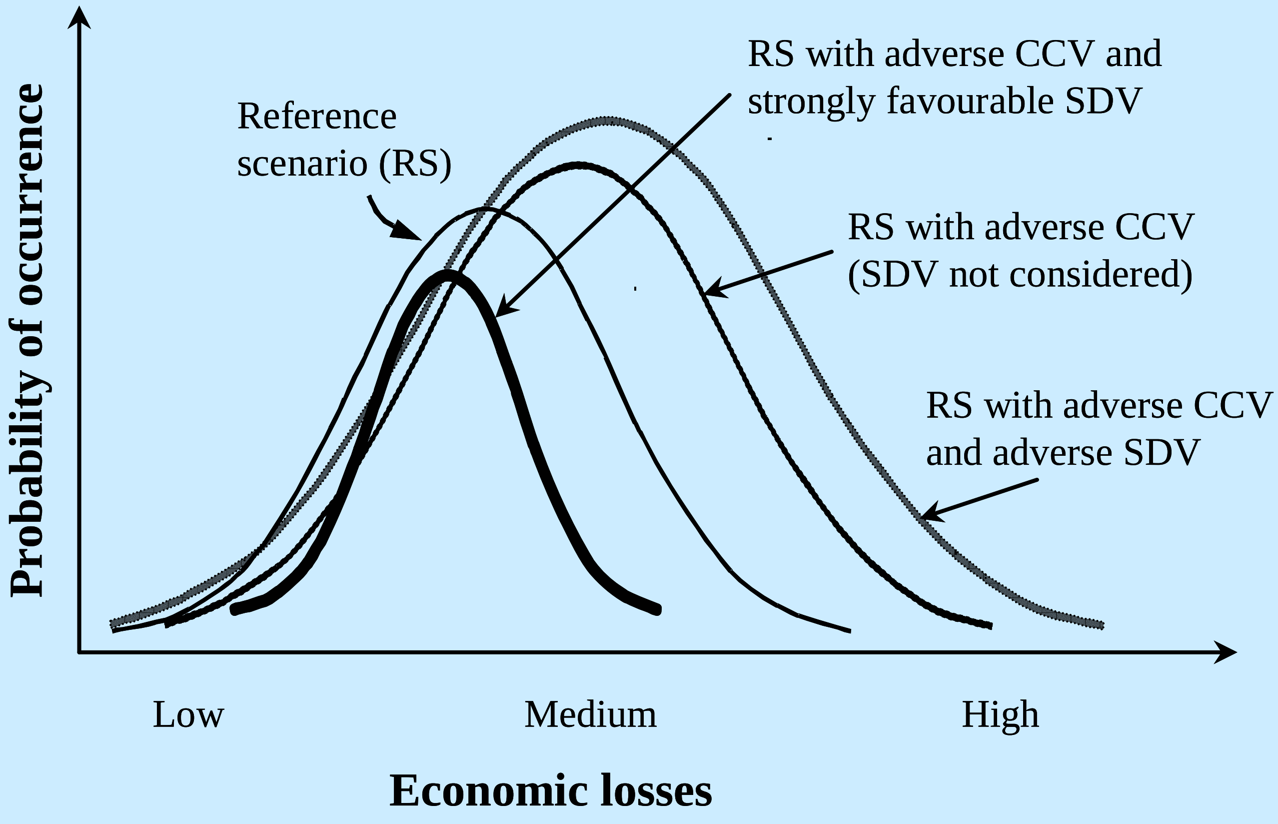
Rainfall variable projections akin to IPCC B2 from *Rupa Kumar et al., 2003*
Forest cover in the year 2000 for concerned districts from *Status of Forest Report, 2002*

Maintenance Cost:
Compound impacts of age and climate change



- 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



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 (*<u>e.g. insurance</u>*) 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:
  - *<u>Quality</u> of development, i.e. development pathway matters*
  - *<u>Mainstreaming</u> Climate change actions accrue <u>multiple dividends</u>*
  - *<u>Interests</u> of projects need to be aligned with <u>development</u> and <u>climate</u> processes*
  - *Early adaptation for aligning <u>financing</u> and <u>technical</u> assessment of projects*
  - *Climate-friendly development should be <u>rewarded</u> rather than <u>under-financed</u>*

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