Case Study: Konkan railway Corporation Limited

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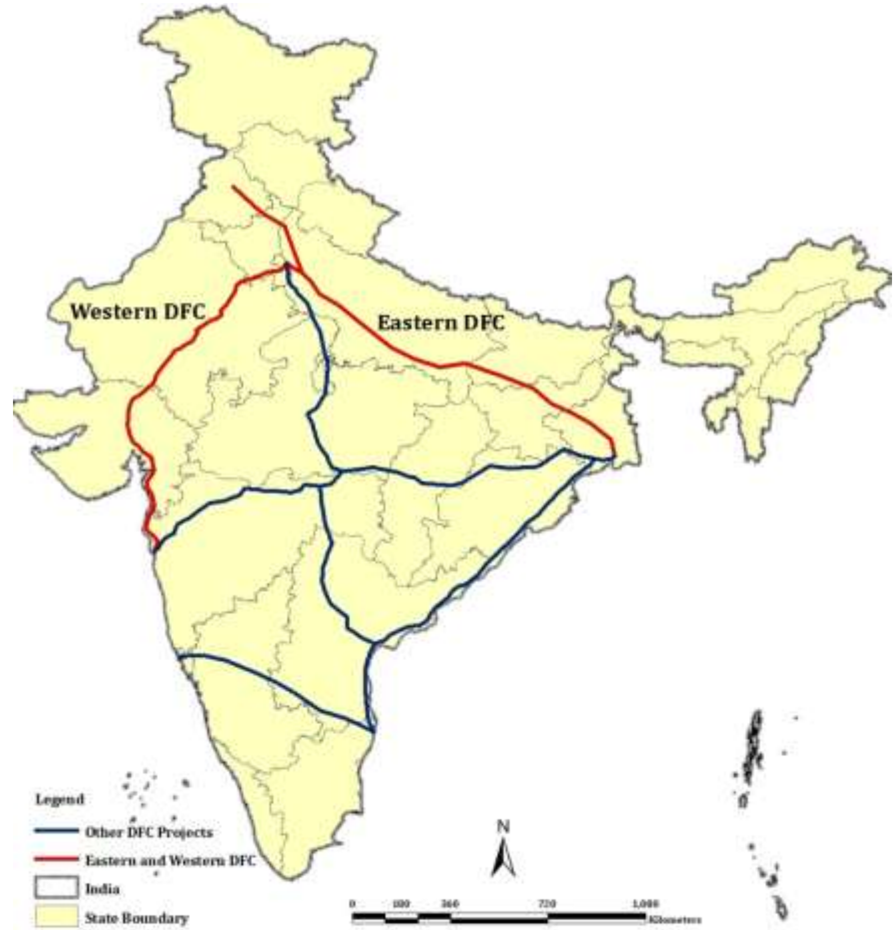
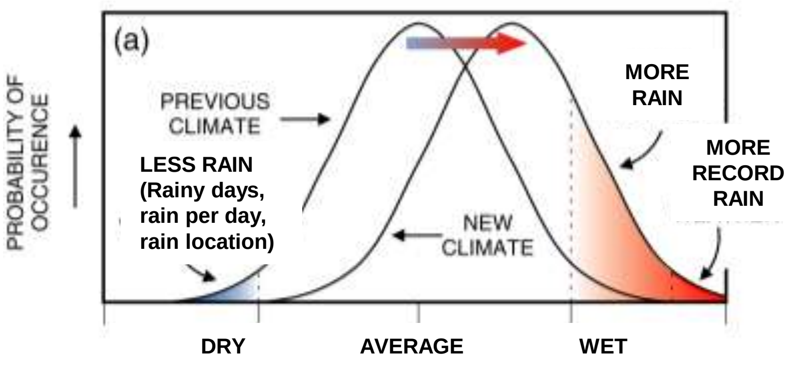
Sustainable (& Reliable) Logistics and Climate Change Risks

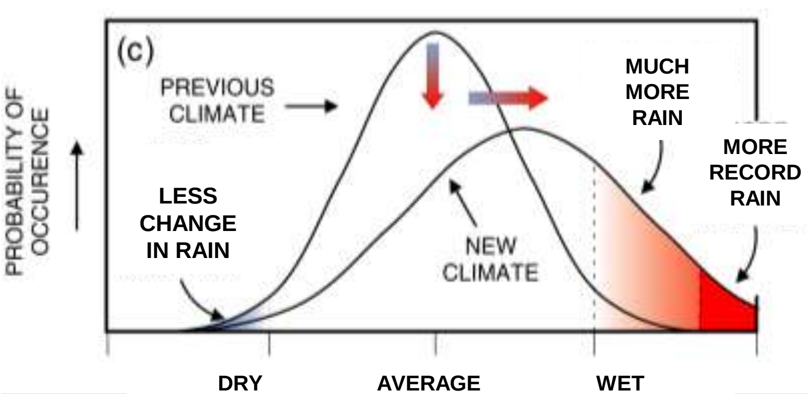
- 47% of Projected Freight Demand will move on DFC's
- DFC's would therefore become critical to national freight movement
- DFC's especially on Eastern and Western ghats could be more susceptible to weather vagaries, as even now the existing railway lines there experience operational difficulties during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



Climate Change Manifestation



Large percentage change in extremes



Much bigger percentage changes in extremes

- 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

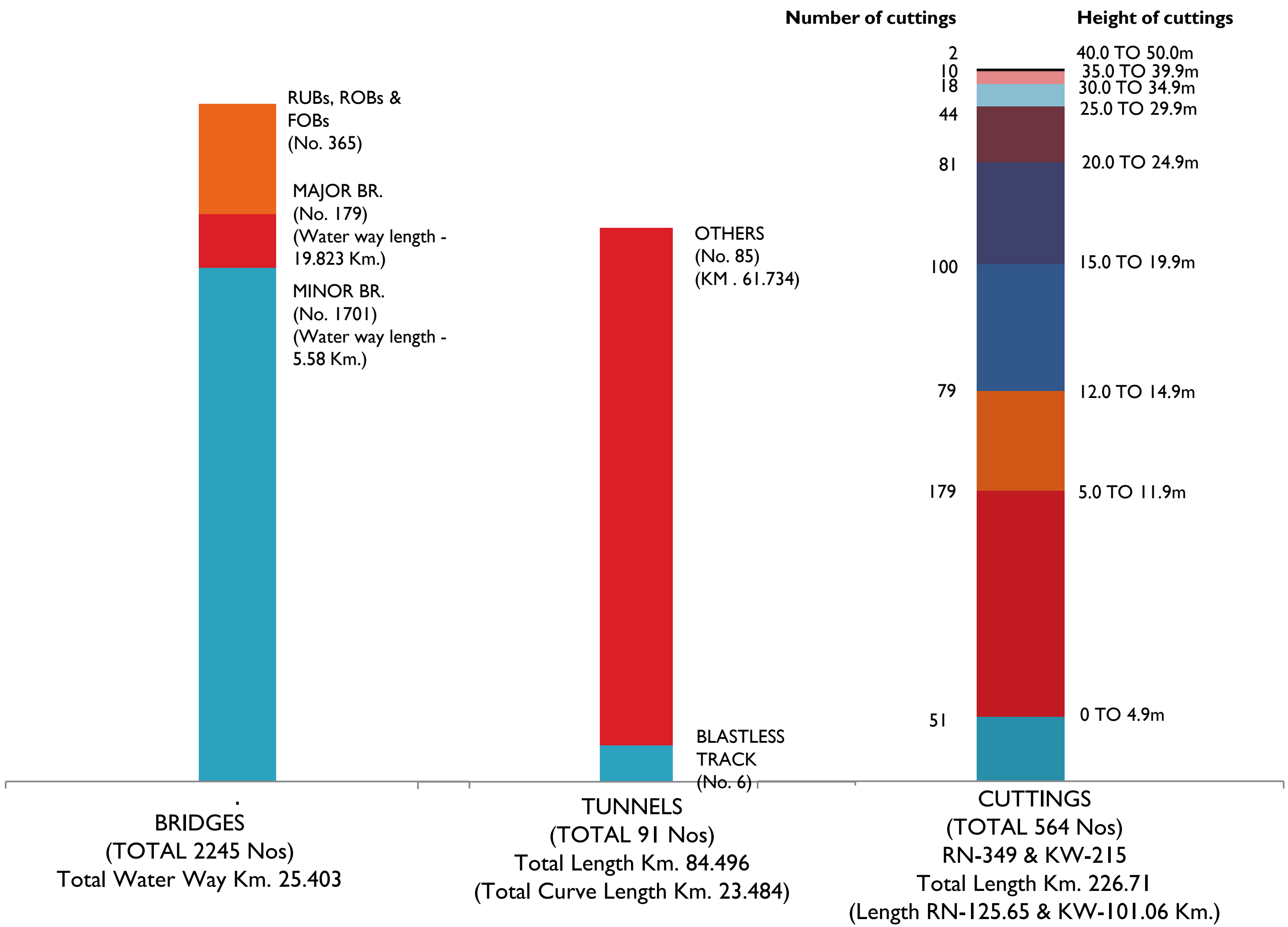
- Two types of risks
  - Implementing safety works for an event that does not eventually occur - Excessive safety? – wasted expenditure? – Type-1 error
  - Not planning for an extreme event which eventually occurs - Lower safety? – exposing passengers and goods to risks? – Type-2 error.
- CC uncertainty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

Source: KRCL

Salient Features of KRCL



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.

http://www.frontlineonnet.com/fl2015/stories/20030801006911900.htm

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.

http://www.hindu.com/2004/06/17/stories/2004061706301100.htm

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

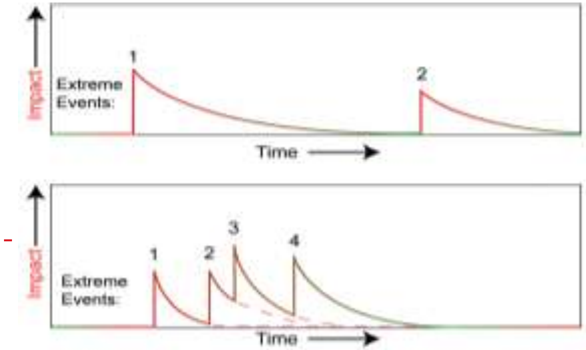
http://manipalworldnews.com/news_local.asp?id=3499

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

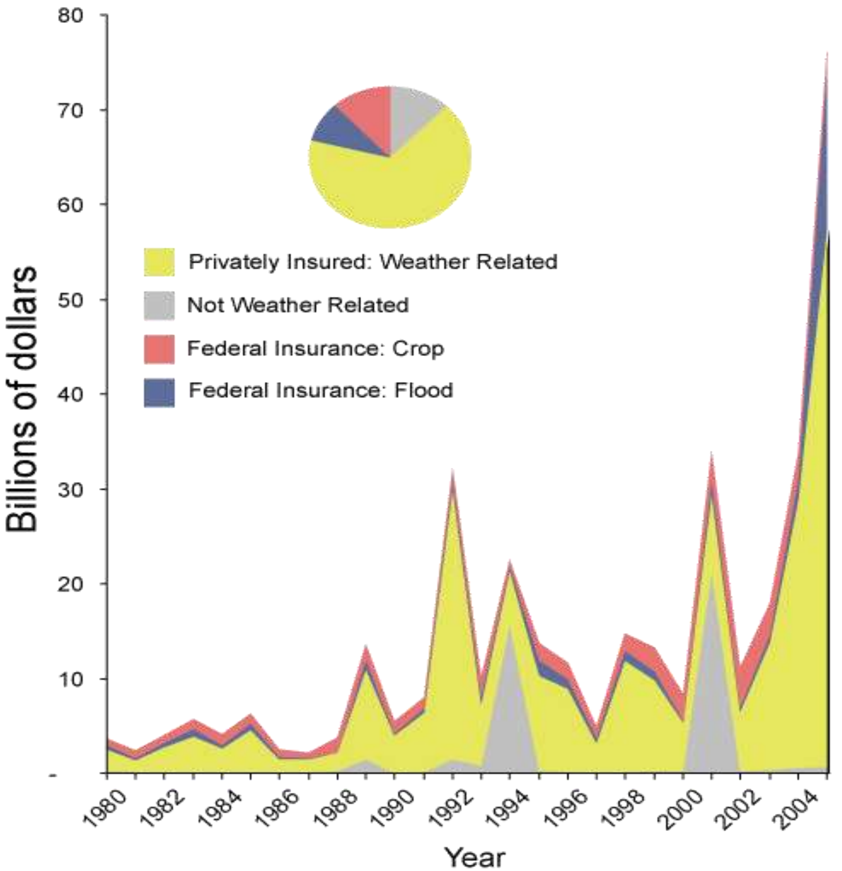
	1970- 2030			
	Mean Annual Rainfall	SD	Mean Annual Temperature	SD
Himalayan	↑↑↑	↑↓↔	↑↑↑	↑↑↑
West Coast	↑↑↑	↑↓↑	↑↑↑	↑↔↔
East Coast	↑↓↑	↓↓↓	↑↑↑	↑↑↑
North East	↑↑↑	↑↑↑	↑↑↑	↑↑↑

Why is it a challenge?

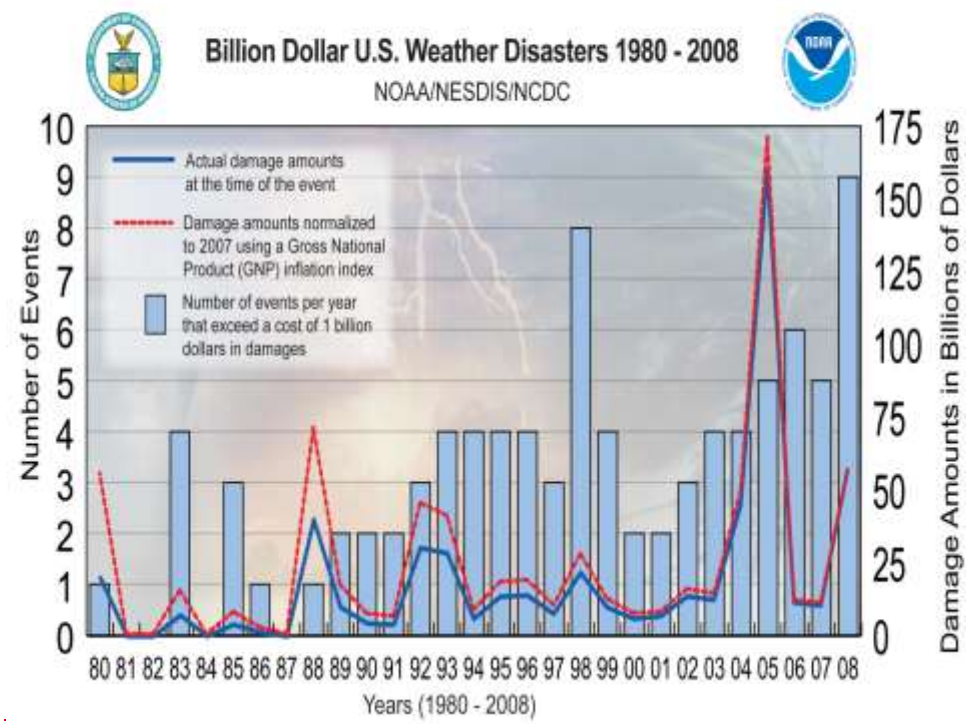


- System thresholds
  - Climate system can react abruptly with limited warning signs before thresholds are crossed – flash floods (Stocker, 1999)
  - More than the averages, it is the extremes events are a cause of concern
    - Extreme Weather Event: An event that is rare at a particular place and time 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

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

Source: Carmianti (2010); Vespermann & Wittmer (2010); Lash & Wellington (2007); IRM, (2002)

Some Impacts (Roads & Railways)

CCC Parameter	Temperature, Precipitation, Extreme Events

Direct Impacts	- Physical Damage
	  - Boulder falling, land slides
	  - Accidents, derailments, curtailed train operations
	  - Joint Expansions, Rail cracks
	- Supply Chain Impacts

Indirect Impacts	- Agriculture production and regional freight traffic - Enhanced cooling / Heating requirements - Modal shifts - Mitigation Pressures
Risk Management	- Technology, e.g. Safety nets, reducing cuttings etc. - Better Communication - Insurance

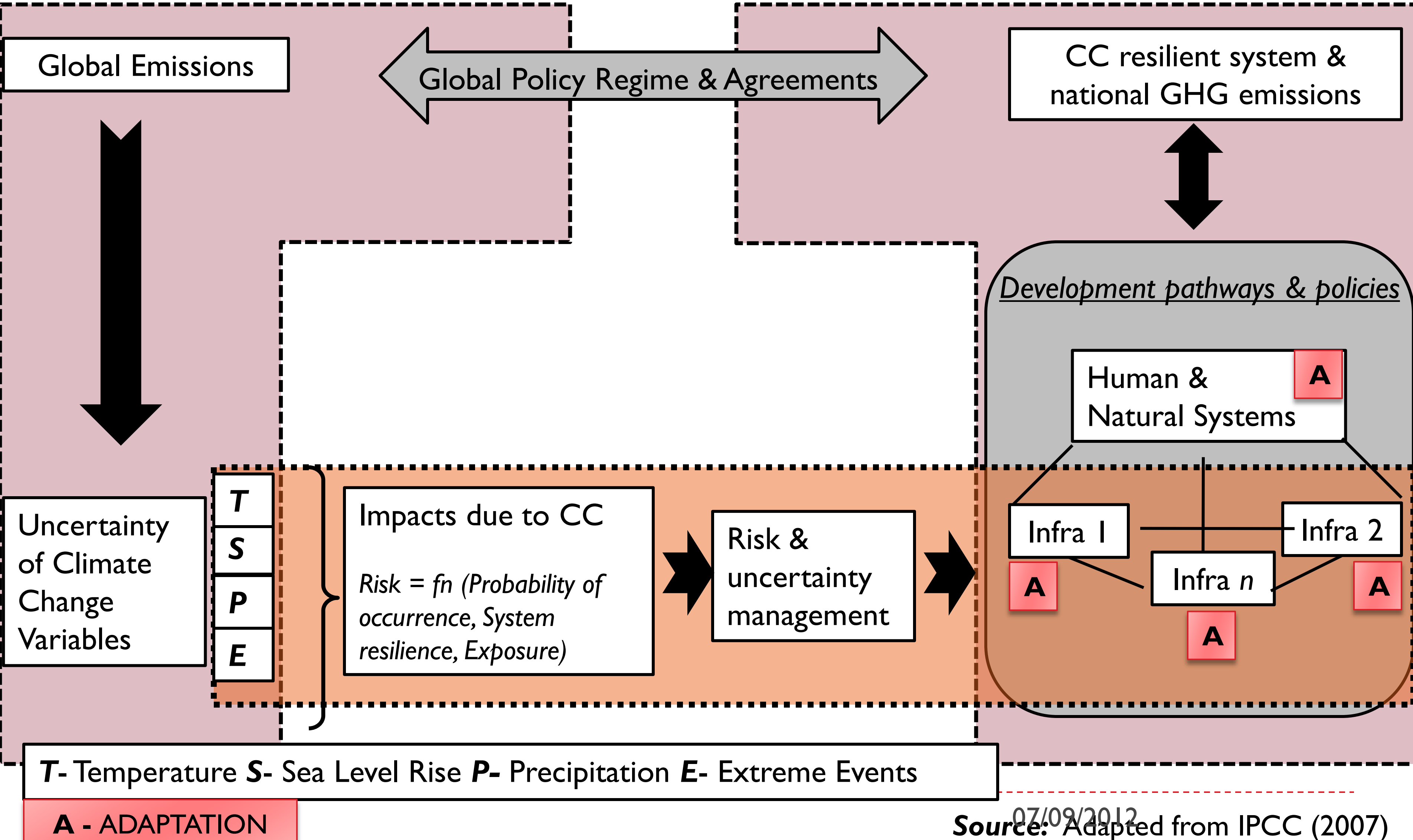
Climate Change Adaptation & Costs

- 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).

Source: IPCC, (2007b); Burton et al (2006); Fankhauser et al (1999)

Analytical Framework

Integrated CC Assessment for Infrastructure



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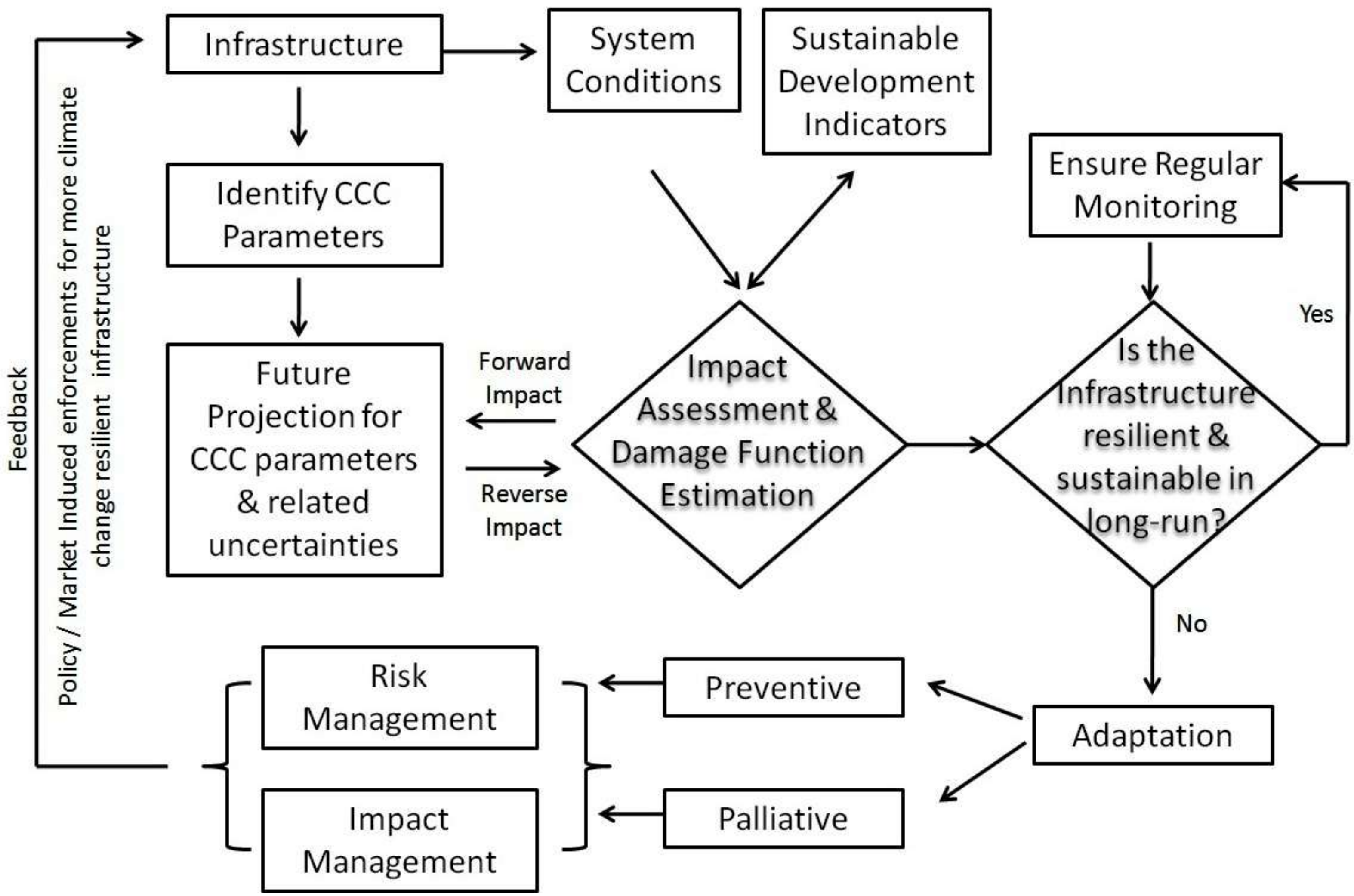
Source: Adapted from IPCC (2007)

Risk Management Framework



Reverse Impact Matrix

Forcing Variables \ Dépendent Variables	***Environmental Variables***	***Project Components***
Environnemental Variables	Quadrant 2: Environnemental impact inter-linkages	Quadrant 3: Reverse Impact (impacts of environment on project)
Project Components	Quadrant 1: Forward Impact (impacts of project on environment)	Quadrant 4: Project's impact on other projects

Source: Kapshe, et al. (2003)

Climate Impact Matrix

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

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*.

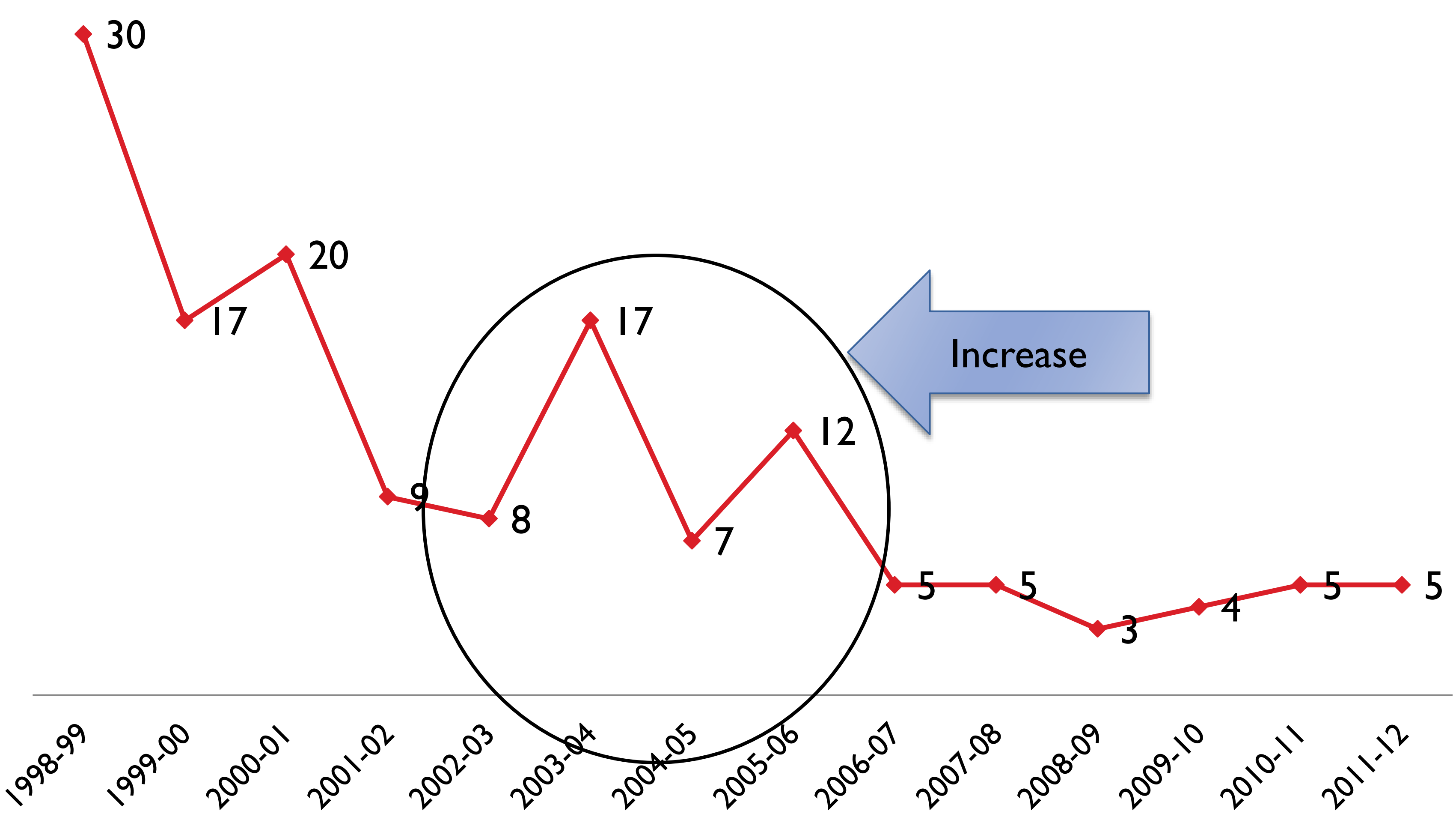
C = Projected climate change scenarios (BAU, A1B, SD)

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

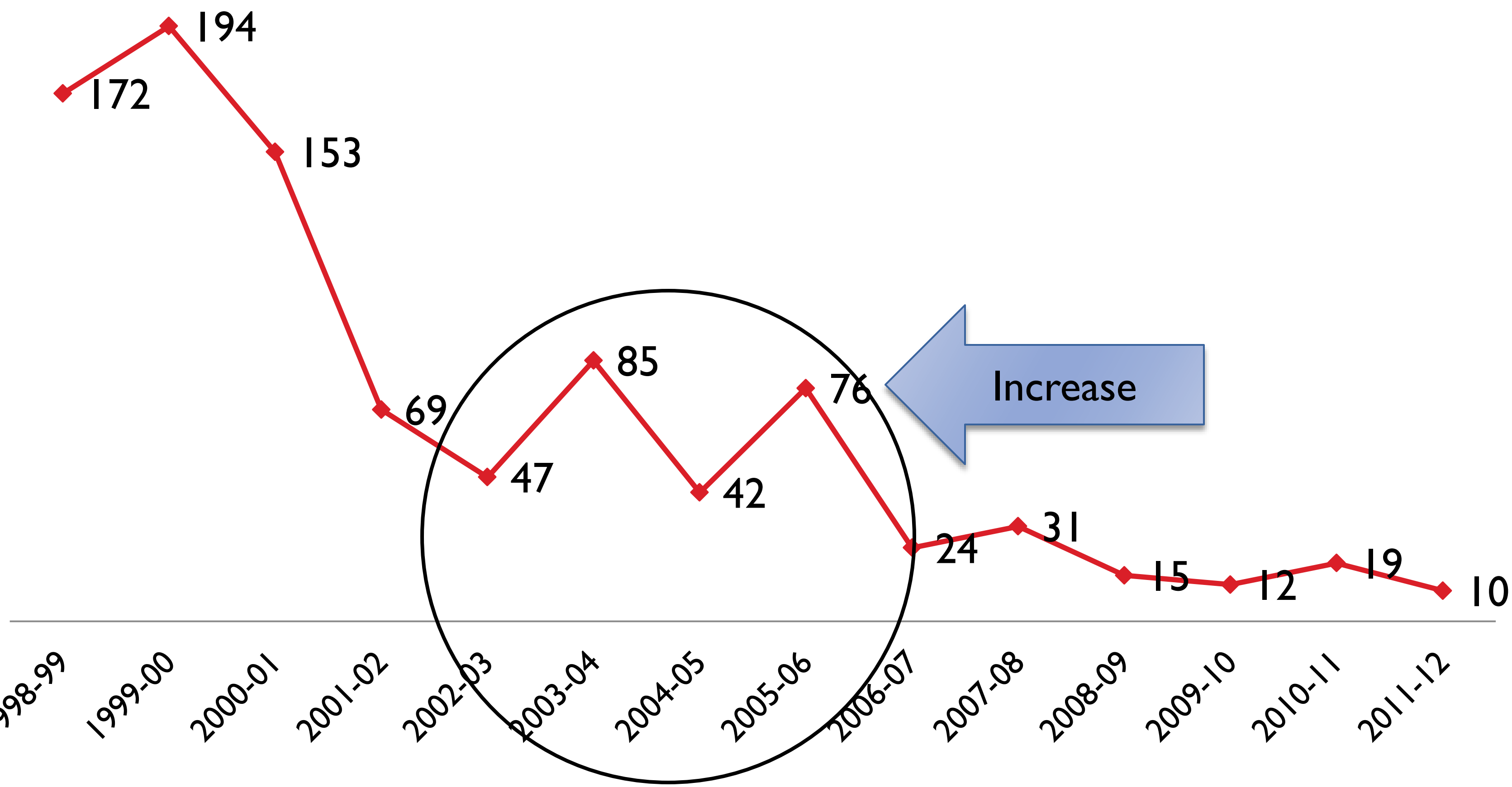
Economic Savings in a SD scenario = E [EL (A1B)] - E [EL (SD)]

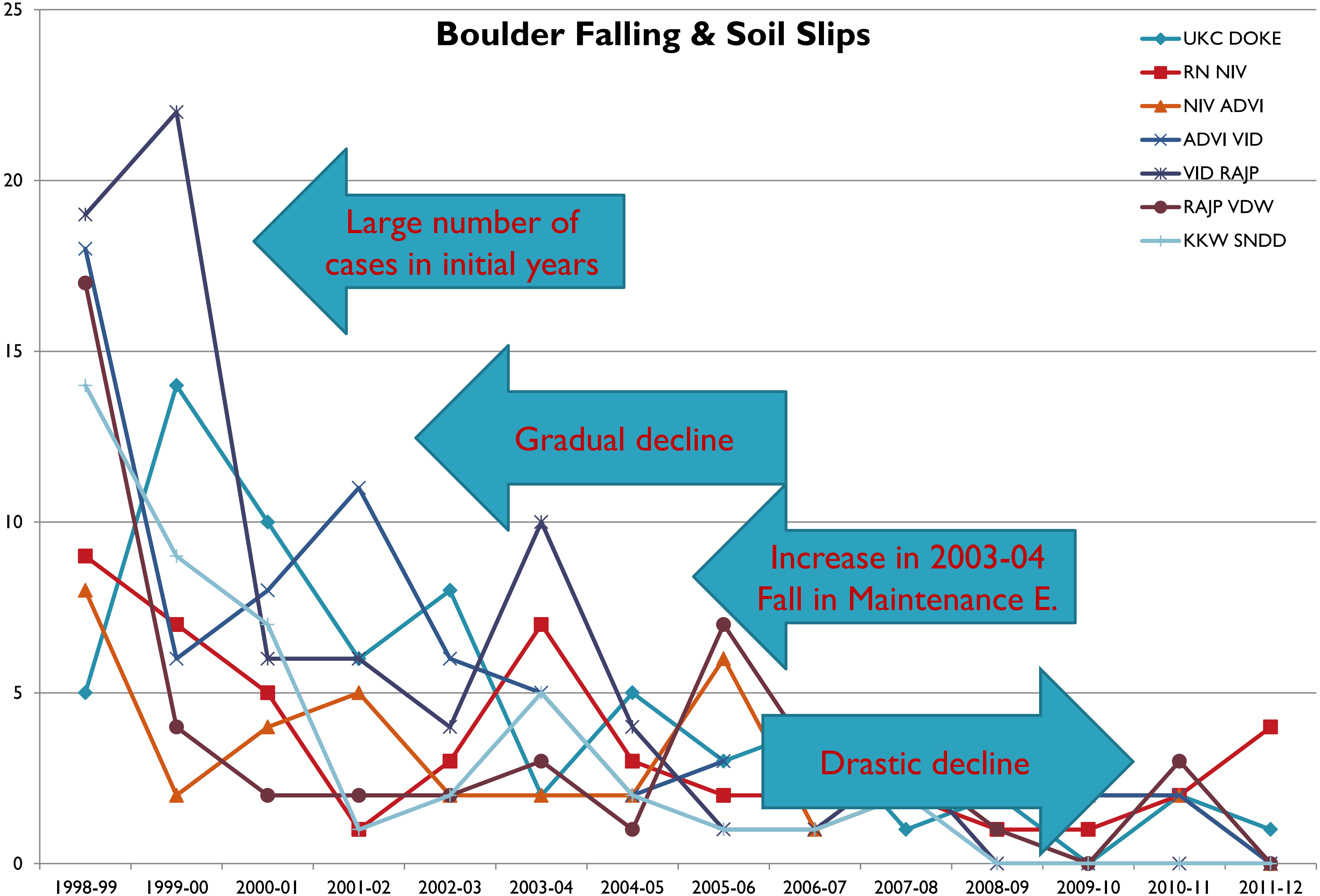
KRCL Event Trends

Boulder falling & Landslides with Traffic Interruptions



Total cases of Boulder falling & Landslides




Boulder Falling & Soil Slips
UKC DOKE
RN NIV
NIV ADVI
ADVI VID
VID RAJP
RAJP VDW
KKW SNDD
Large number of cases in initial years
Gradual decline
Increase in 2003-04 Fall in Maintenance E.
Drastic decline
0
5
10
15
20
25
1998-99
1999-00
2000-01
2001-02
2002-03
2003-04
2004-05
2005-06
2006-07
2007-08
2008-09
2009-10
2010-11
2011-12

Maintenance Expenditures

Year	Bridges & Tunnels	Plant & Equipment	Permanent Way	Stations & other Buildings	Rolling Stock
1995-96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1997-98	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2003-04	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2004-05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2005-06	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	24,707,595	106,687,318	279,731,580	65,470,209	53,849,548

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

6 Times | 6 Times | 5 Times | 37 Times | 10 Times

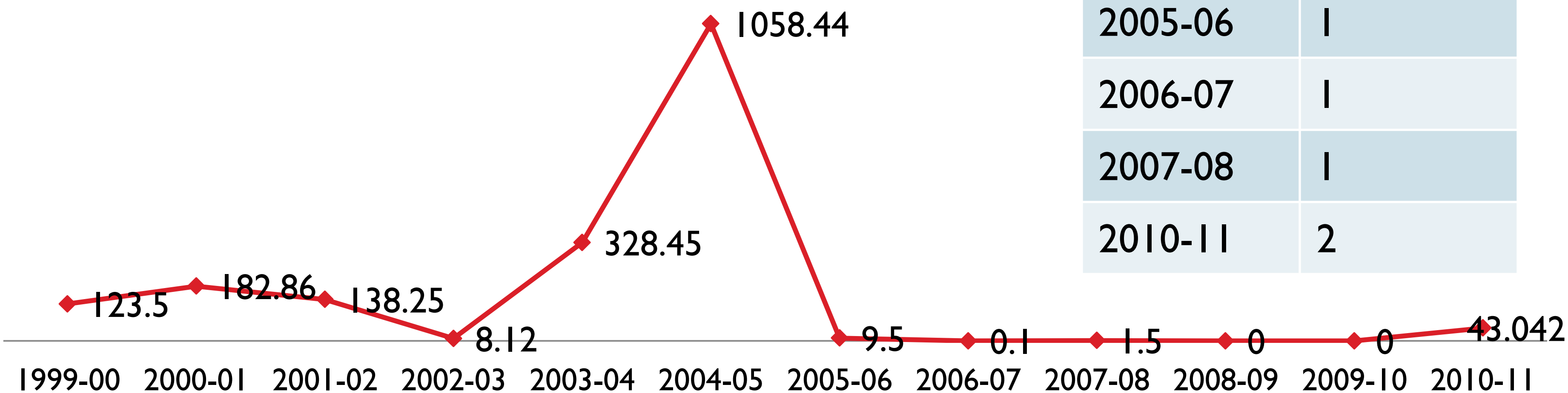
Decrease in YoY maintenance spending

Accident Statistics

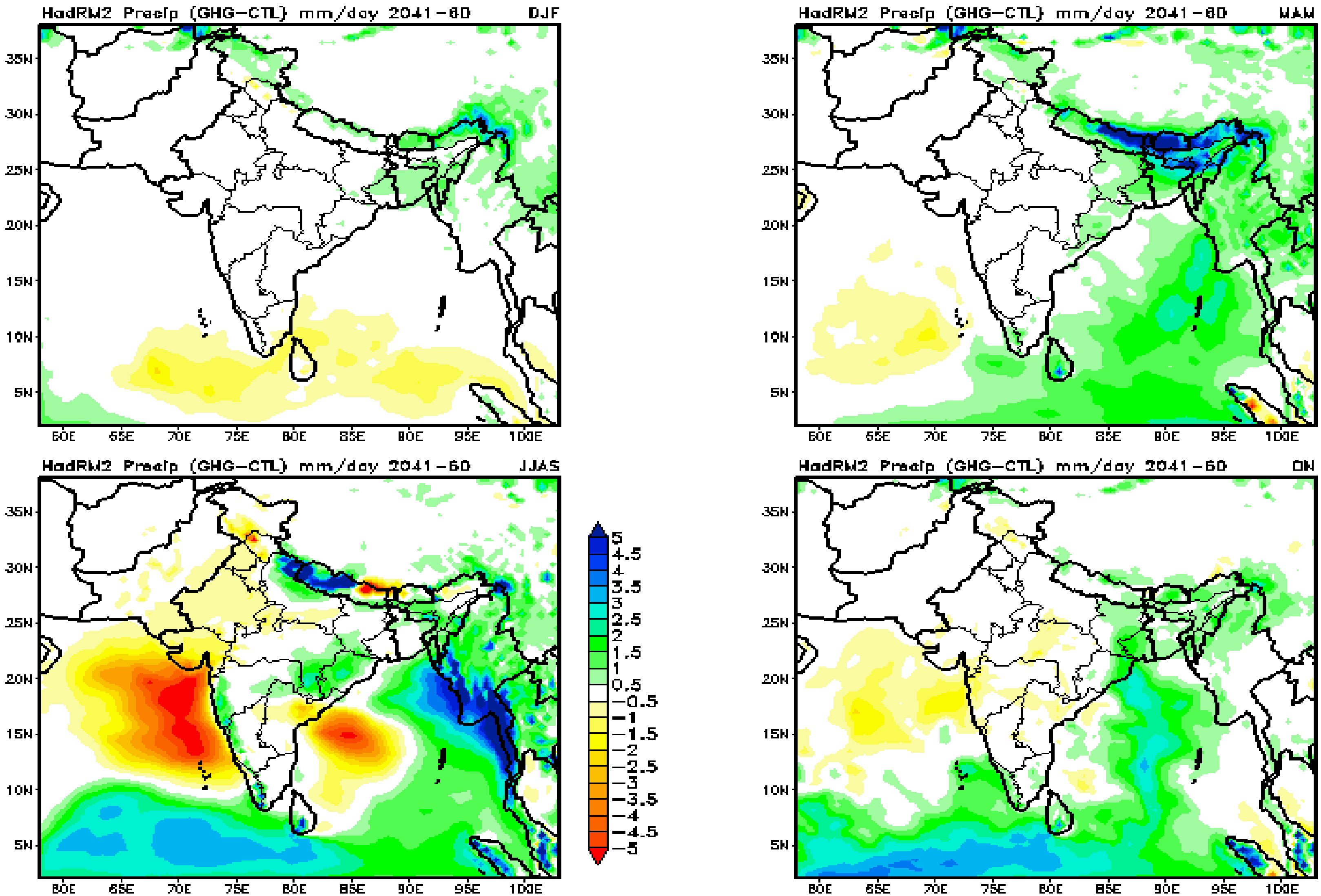
Cause	Proportion	#
Natural	61.54%	16
Material Failure	11.54%	3
Failure of Railway staff	15.38%	4
Others	11.54%	3

Year	#
1999-00	4
2000-01	9
2001-02	1
2002-03	2
2003-04	5
2004-05	2
2005-06	1
2006-07	1
2007-08	1
2010-11	2

Damage in Rs Lakhs

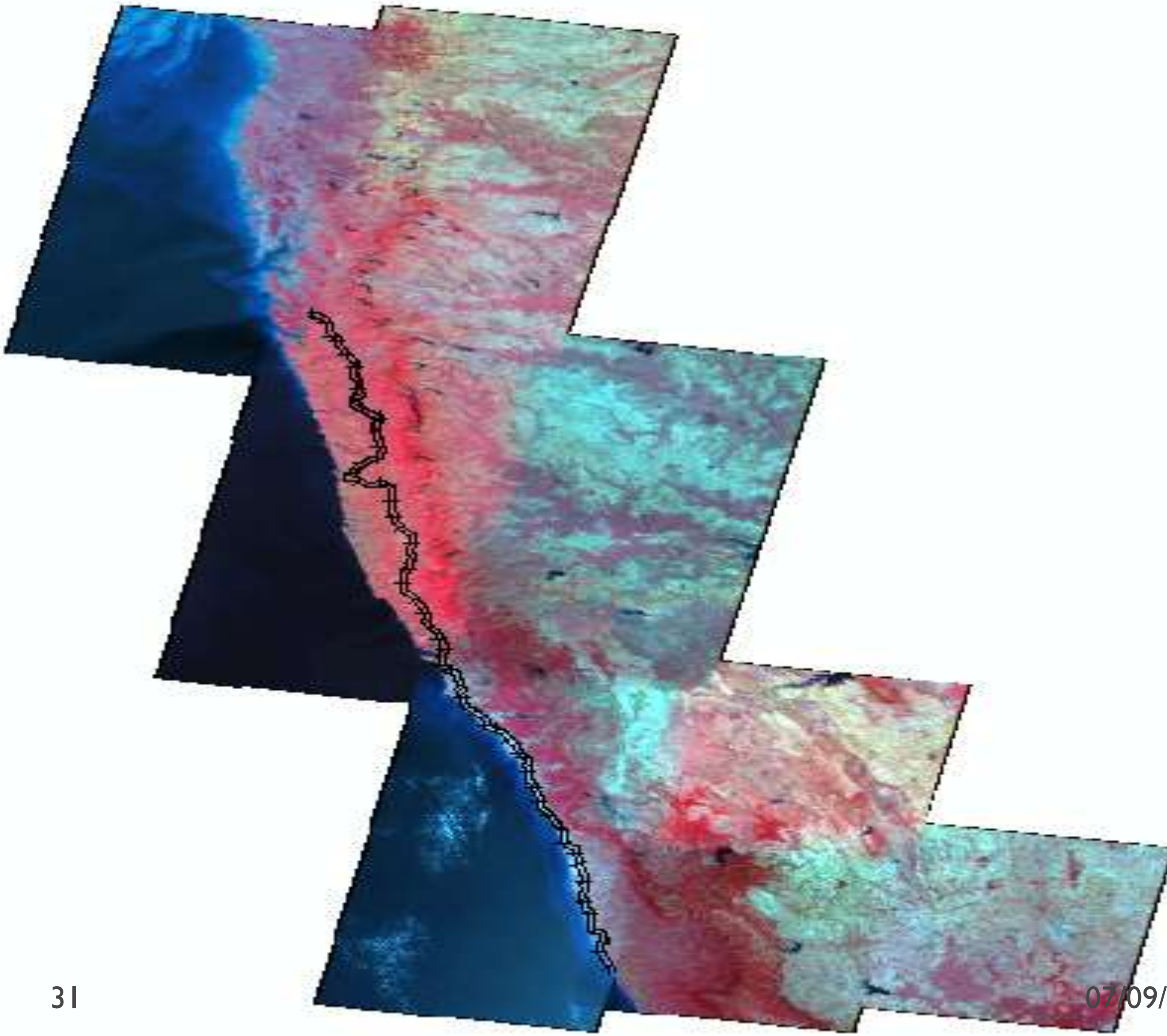


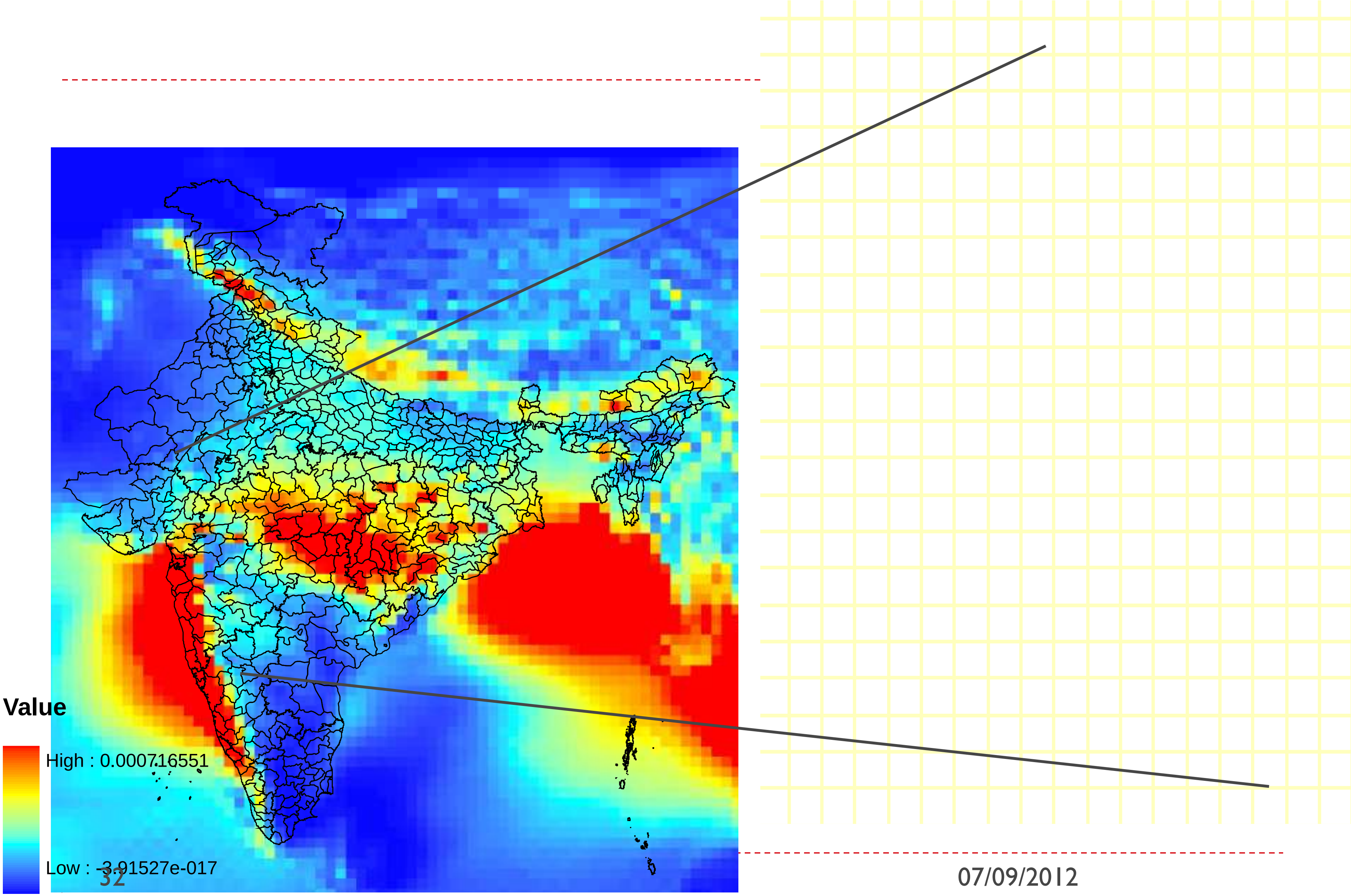
Rainfall Pattern

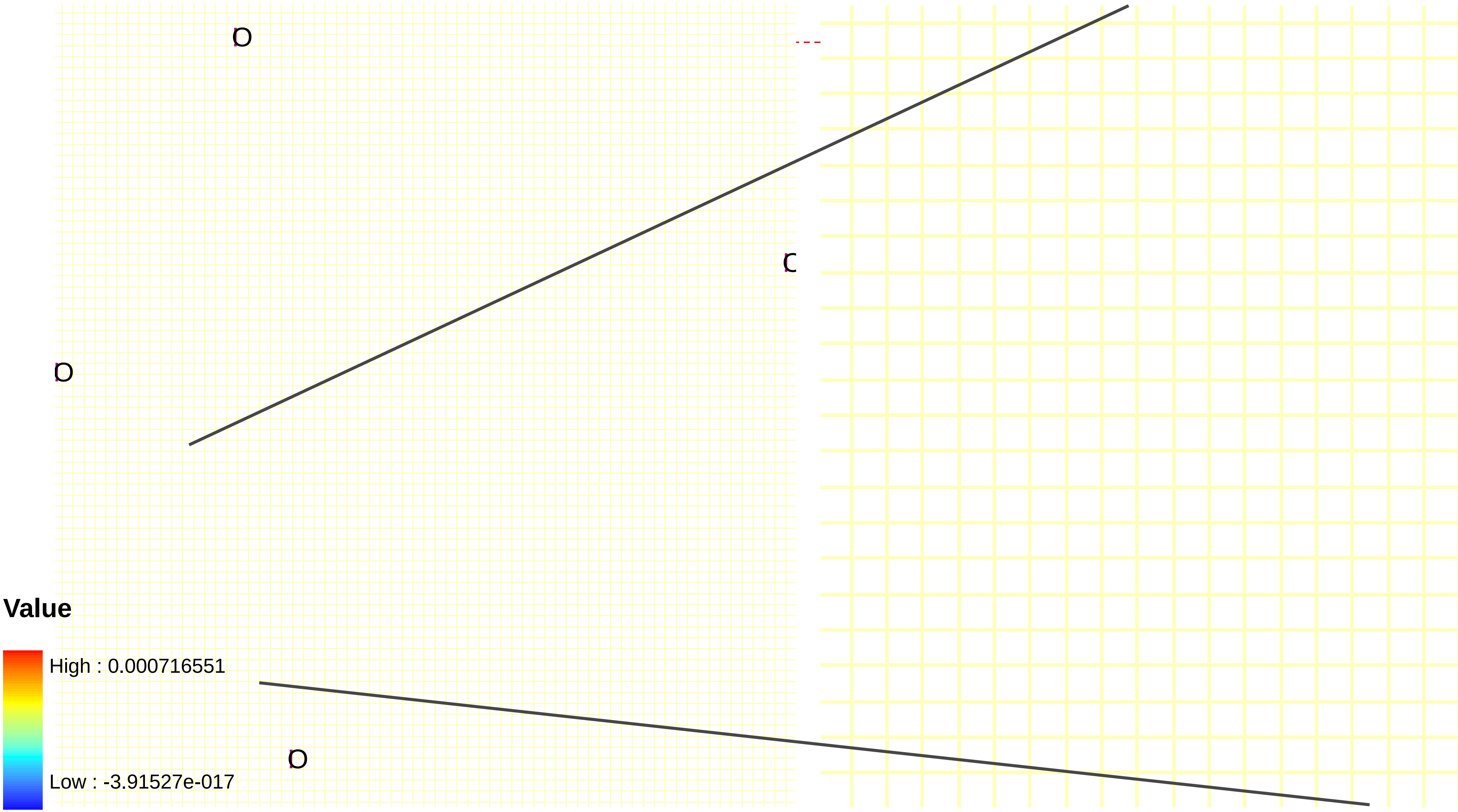


Spatial pattern of projected seasonal precipitation change (mm) for 2050 relative to 1990s

Konkan Rail Route overlaid False Color Composite (LANDSAT TM- Mosaic Images (1999-2000 & 2001)

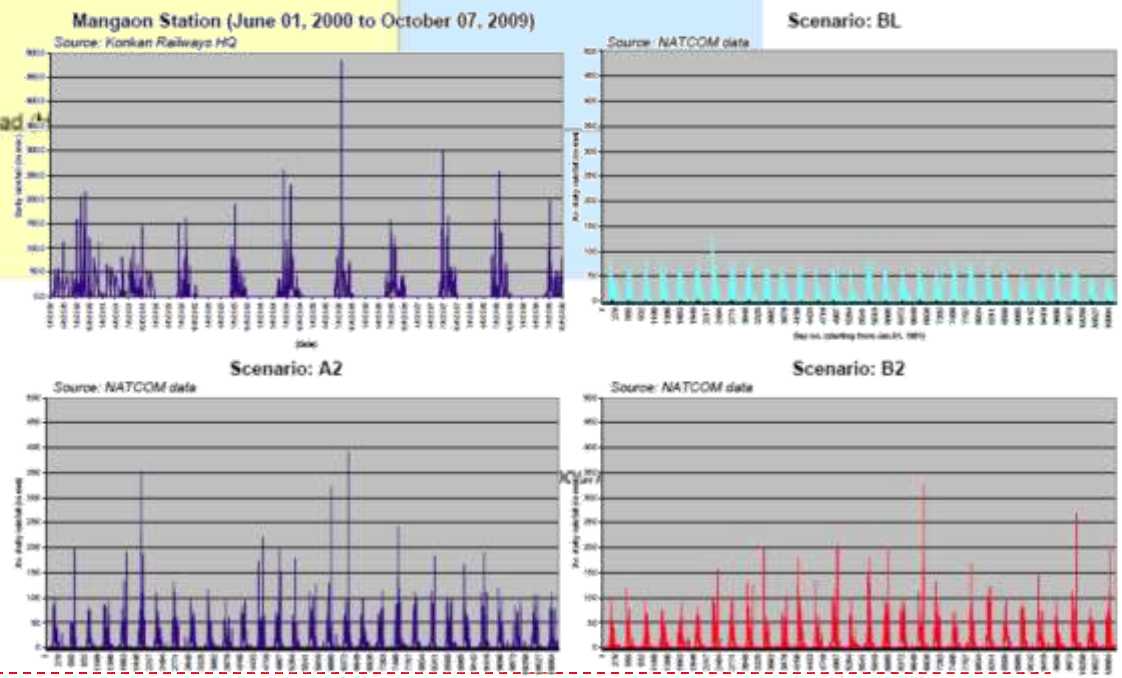



Value
High : 0.000716551
Low : -3.91527e-017


Value
High : 0.000716551
Low : -3.91527e-017

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

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

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

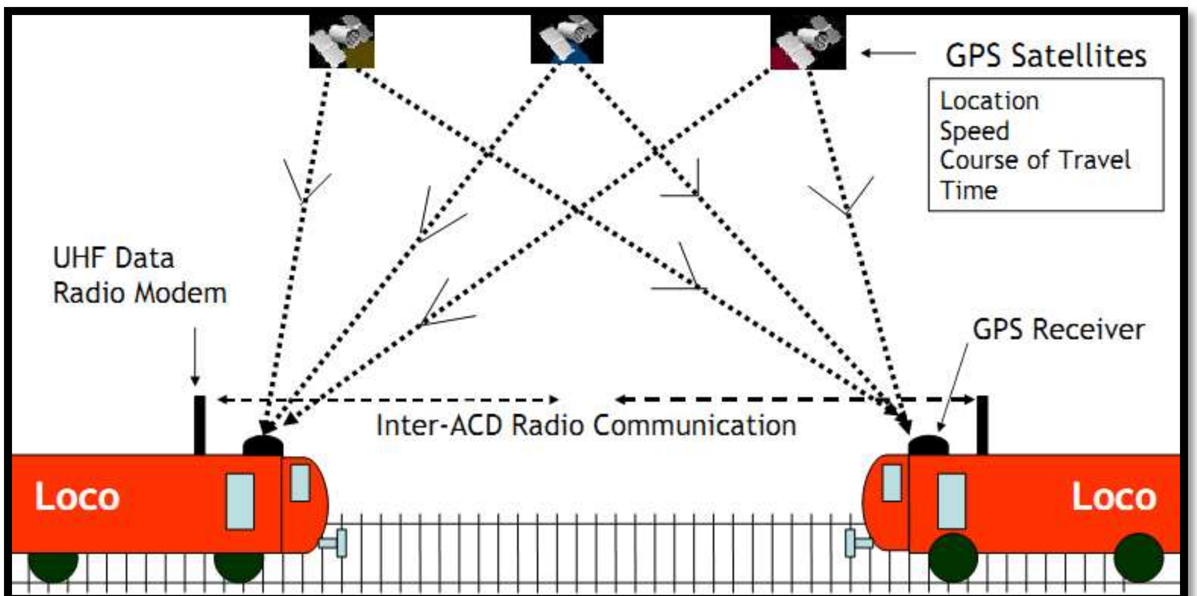
Current Geo-tech Safety Works

- Flattening of slopes
- Construction of
  - Toe walls
  - Ballast retainer walls
- Lining of catch water drains

Technology currently in use

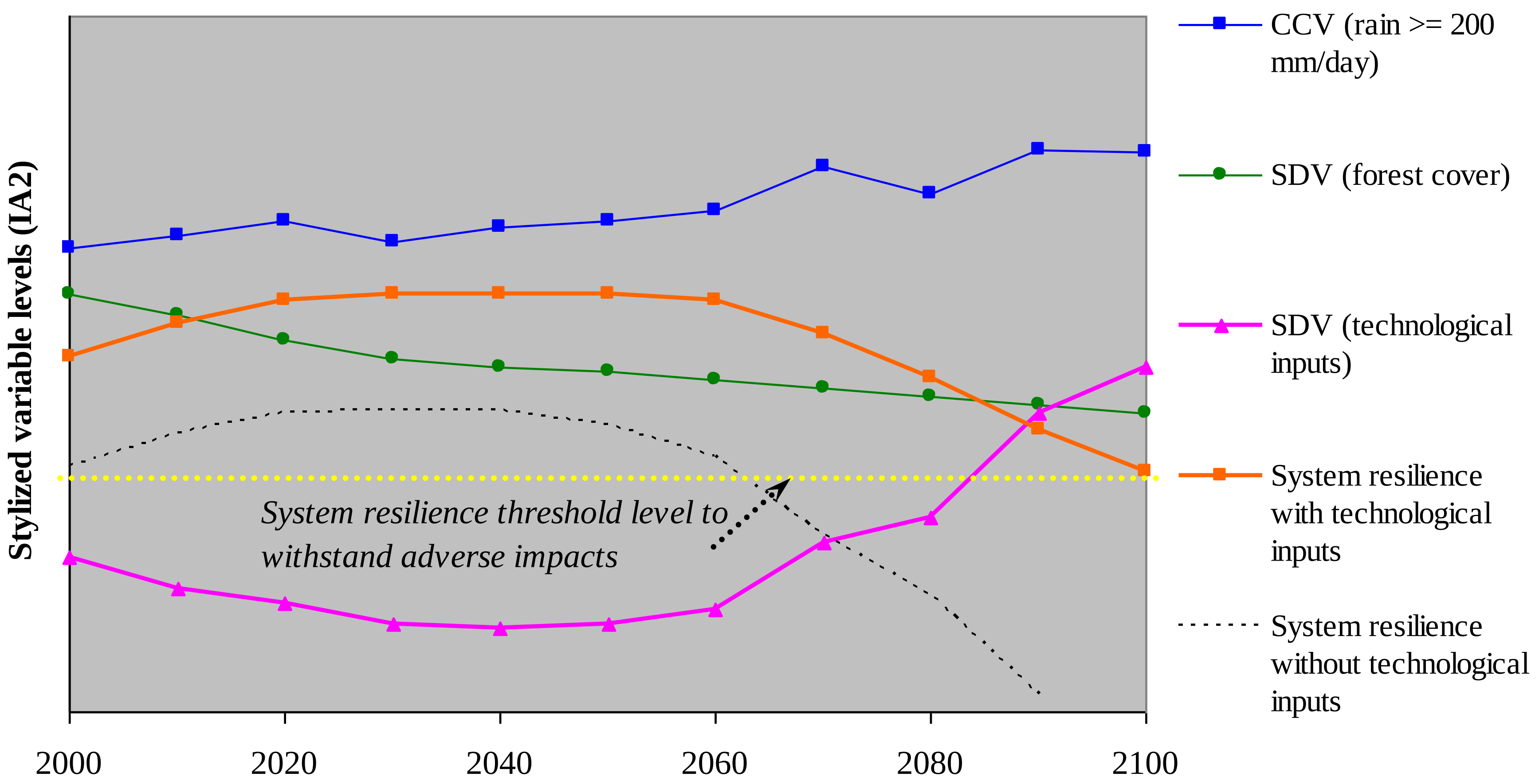
- <u>RakshaKavach - Anti-Collision Device Network</u>

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'

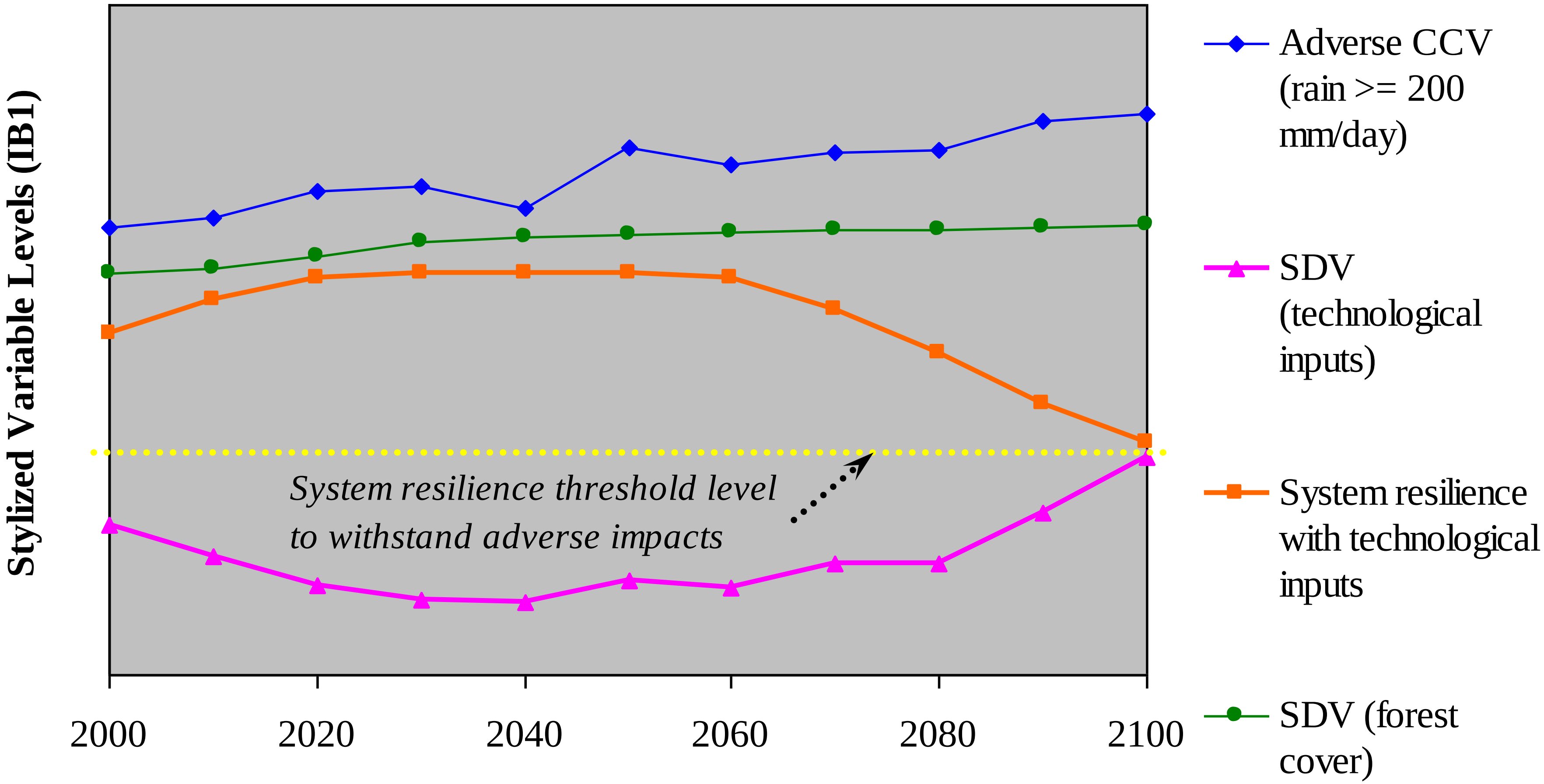


Analysis and Conclusions

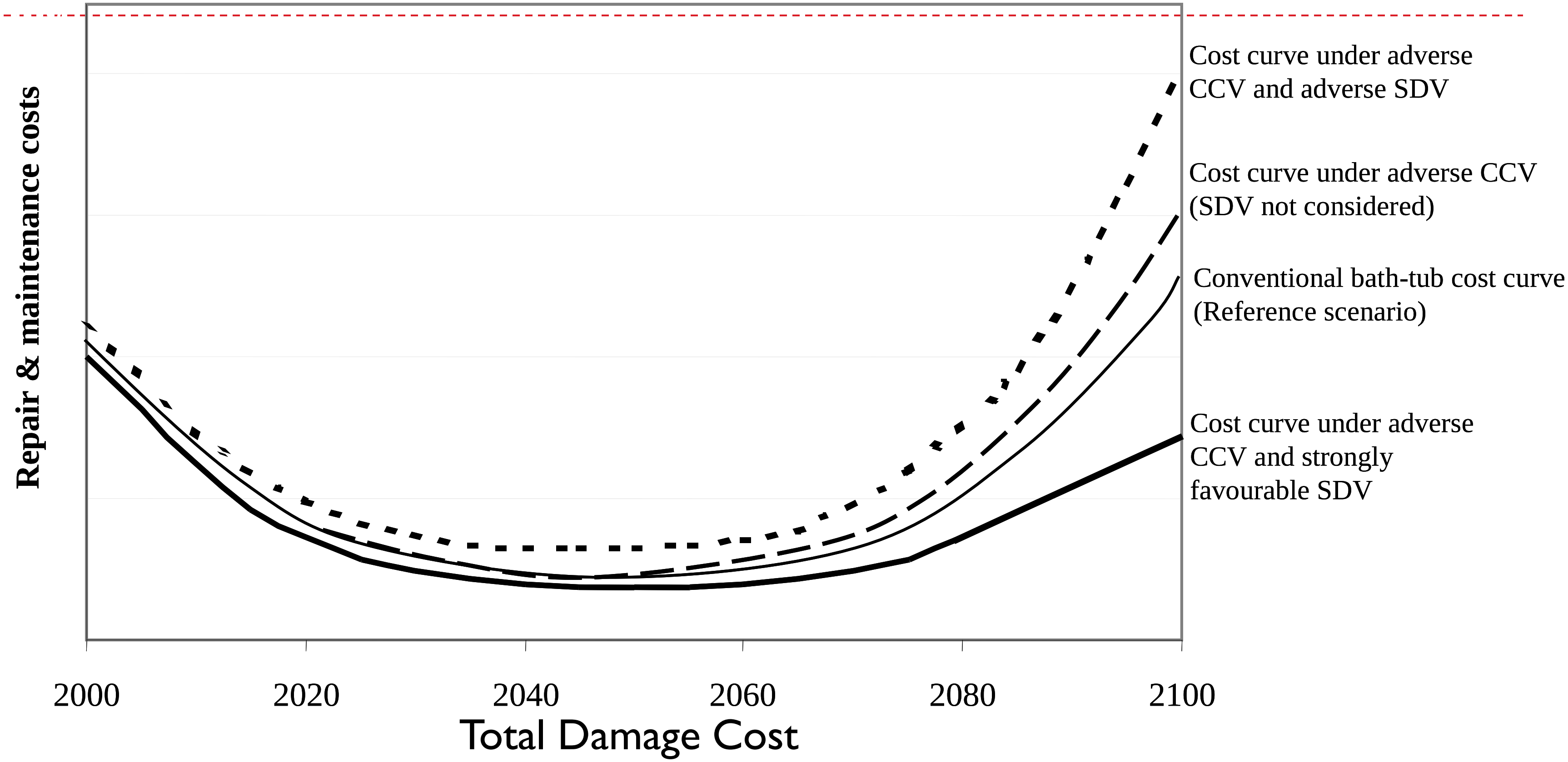
Stylized interaction of relevant CCV with SDV (Under BAU)



Stylized interaction of relevant CCV with SDV (Under SD)

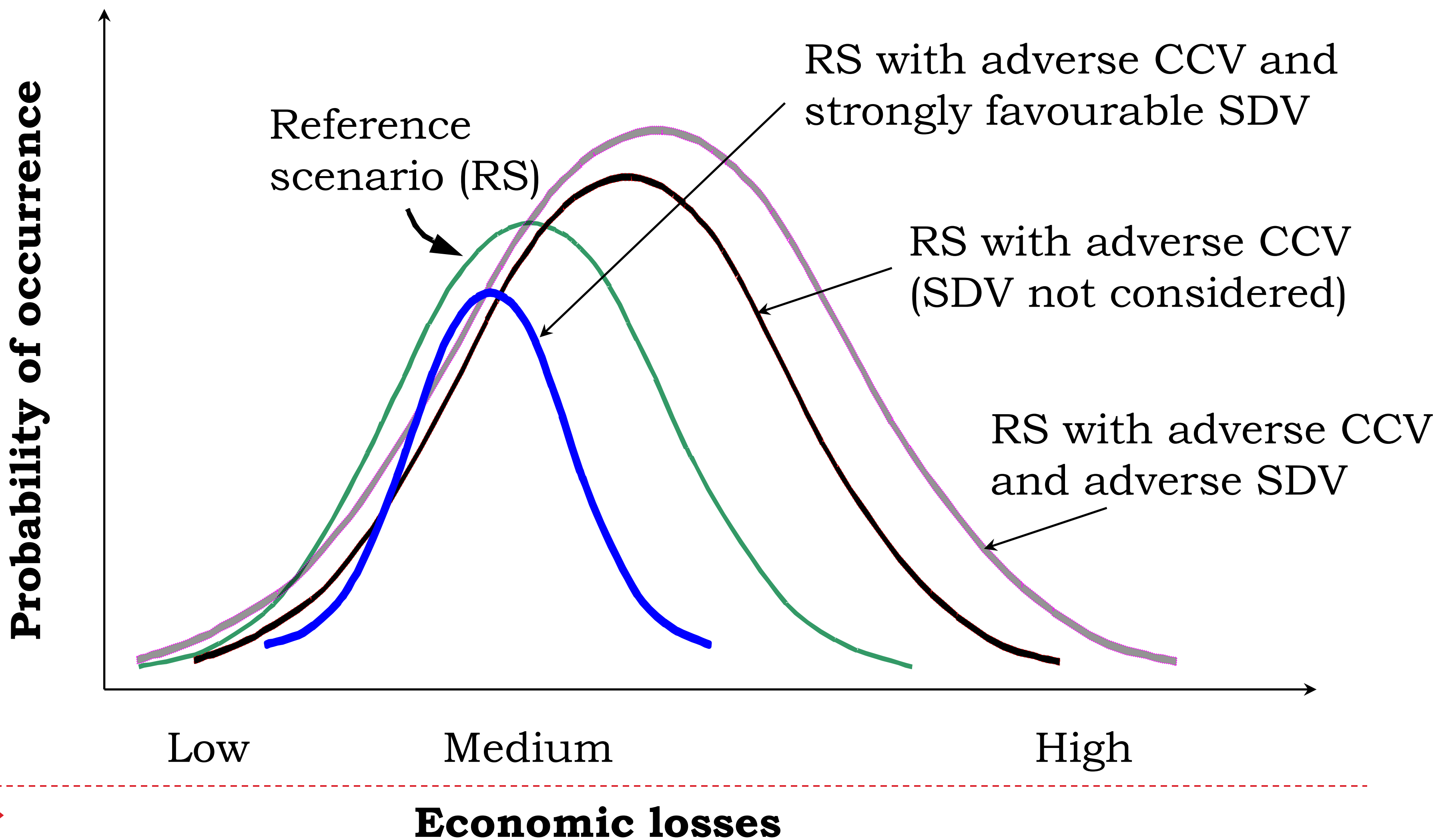


Damage Cost: Integrating SC, CCV & SDV Impacts



- 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



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)

Sr.NO	ITEM OF WORK	UNIT	QUANTITY EXECUTED	Cost of work done (`. in Crores)
1	Earthwork for flattening of slope & creation of berms & Refixing of HSBN	Cum	245000	6.25
2	RCC Retaining wall and Gabion wall.	Cum	3874.20	2.42
3	a) Shotcreting	Sqm	11255	1.97
	b) Rock Bolting	MT	44.55	
4	Pitching	Cum	535.54	0.01
5	Catchwater drain (CWD) lining	Cum	1134.32	0.67
6	Soil naling	Rmt	5239.00	0.72
			TOTAL	**12.04**

The cost abstract of yearwise planning of permanent measures

All figures are in `crores

Description of work	2011-12	2012-13	2013-14	2014-15	2015-16	Total
Flattening of slopes in cuttings, retaining wall, lining of catch water drains and side drains, etc.	40	60	60	70	70	300
Rock bolting and shotcreting in Tunnels.	10	10	10	10	-	40
TOTAL						340

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

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

Abstract of Year wise expenditure

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

Short Term solutions

Climatic Parameter	Impact Parameter	Intervening Parameter	Impact on KRC	Short Term Solutions
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

Climatic Parameter	Impact Parameter	Intervening Parameter	Impact on KRC	Short Term Solutions
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

Climatic Parameter	Impact Parameter	Intervening Parameter	Impact on KRC	Short term Solutions
Sea Level Change	Land Erosion	Tracks tunnels and bridges may be affected	Increased maintenance	1) Increased long term spending will be required for rock bolting.
	Flooding	Land Stability and land slides	Damage to infrastructure. Reconstruction and Relocation	Improve drainage facilities on the tracks
	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	Long term solutions like insurance are needed
	Cloud bursts	Land erosion, floods, and land slides	Extensive damage to infrastructure, High cost of repair and reconstruction	Long term solutions like risk transfer i.e. insurance are needed