CLIMATE CHANGE RISK ASSESSMENT AND ADAPTATION

BHUTAN CASE STUDY

(DEOTHANG-NGANGLAM ROAD)

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WORKSHOP ON CLIMATE CHANGE AND DISASTER RISK MANAGEMENT IN PLANNING AND INVESTMENT PROJECTS

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ADB TA-7608 REG: **"Enabling Climate Change Responses in Asia and the Pacific – Building Resilience to Disaster and Climate Change Impacts (Subproject 2)".**

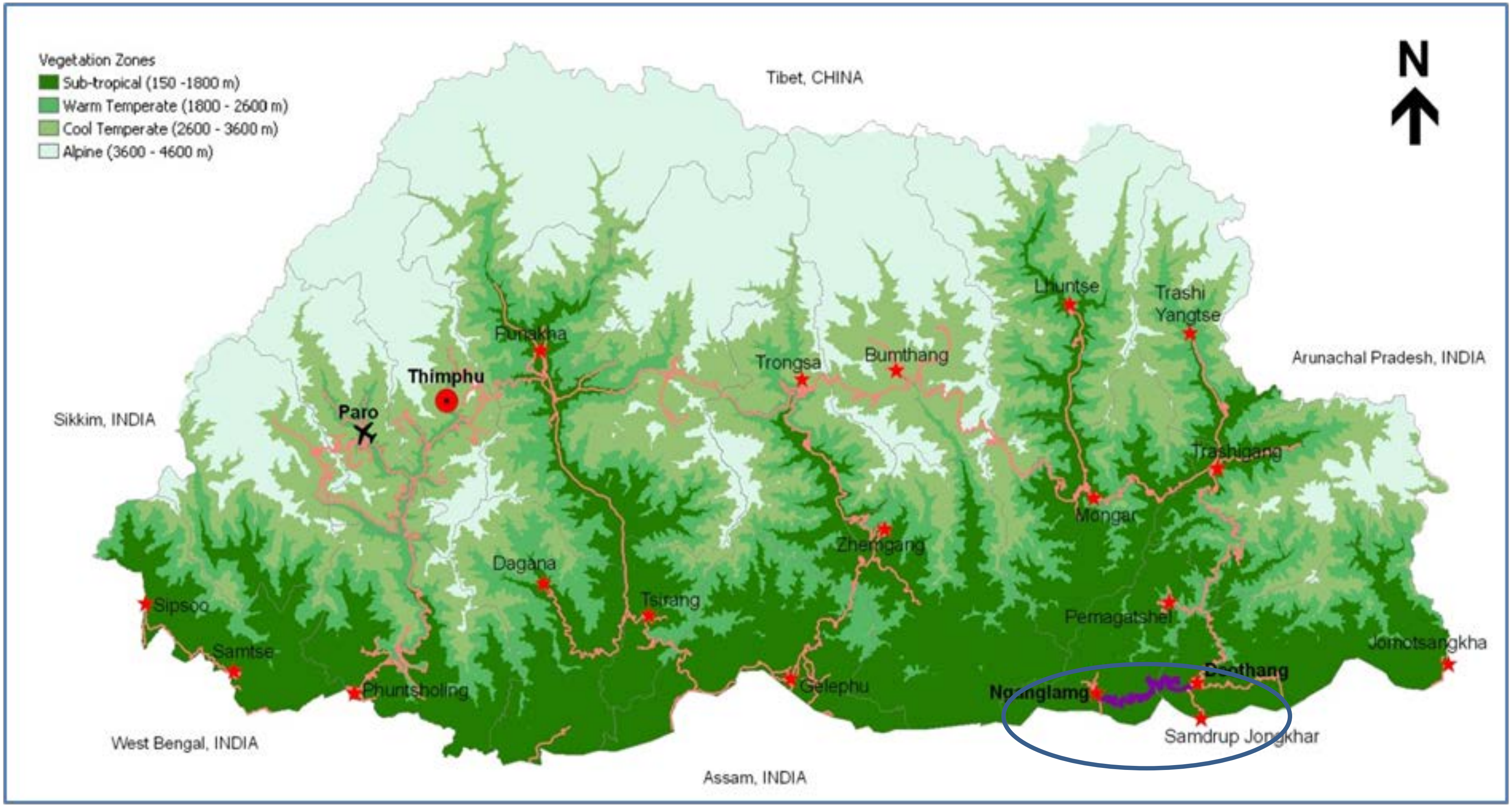
INTRODUCTION

- The above project in Bhutan is specific to "Road Network Project II – Additional Financing" (RNPII-AF), where Bhutan plans to build its second east-west highway to improve trade and rural connectivity in the southern part of the country. This highway is expected to provide additional connectivity to India, increase regional trade and open up internal areas of Bhutan.

The TOR

- (i) the identification of climate change risks and vulnerabilities of the project roads based on hydrological studies using climate projections for the project area; and (ii) provide recommendations on addressing the risks through appropriate adaptation measures in the design of drainage structures and slope protective structures and other measures suitable for the project road.

THE PROJECT AREA
(General Physiographic Map of Bhutan)



In general, the climate in Bhutan varies according to latitude and altitude, the latter being a predominant governing factor. The project area lies within hot and humid subtropical forests. The highest elevation of the proposed highway is at around 1000 m.

THE PROJECT AREA
(Topography of the Road Alignment)

68.3 km of double lane highway connecting two major settlements of Deothang and Nganglam

On Project Specific (Deothang-Nganglam Road)

- Climate data from Meteorology Section; Hydro Met Services Division, Department of Energy, Ministry of Economic Affairs, Thimphu. (total daily series of rainfall, max and min temperature, wind speed, sunshine hours, relative humidity, etc. from 1996 till 2011; (16 years)
- Data from at least 11 met stations along the southern foothills of Bhutan, within latitude of influence of $26.75^0 – 27^0$ North were available.
- Of the 11 met stations, 4 are Class A Met stations and 7 Class C.
- Irregular data records persist at Class-C stations due to lack of trained manpower responsible for the upkeep and recording of consistent data at these stations. Those data were left out from the analysis.

CLIMATE CHANGE PROJECTIONS BY AVAILABLE LITERATURE SPECIFIC TO BHUTAN

1. *Climate Change Impact and Vulnerability in the Eastern Himalayas – Technical Report 4, 2009, ICIMOD – (report presents a significant change scenario of temperature and precipitation in the eastern Himalayas using 20-yr observational data (1981-2000)*

1.1 Temperature Projections for Eastern Himalayas as under: The highest mean temperature increase of 3.2^{0}C projected during winter (December-February) and post monsoon (September-November) and the lowest increase of 2^{0}C during the pre-monsoon period (March-May), and indicates annual mean temperature increases of 2.9^{0}C by the middle of the 21st century.

– In 2020's → warming up by 1.4±0.3^{0}C
– In 2050's → warming up by 2.5±0.4^{0}C
– In 2080's → warming up by 3.8±0.5^{0}C

1.2 Precipitation Projections

- An increase in rainfall during the monsoon, with a 7% increase in monsoon precipitation over the eastern Himalayas by the middle of the 21st century, and an increased intensity of extreme rainfall events. These are expected to cause an increase in the frequency and intensity of natural disasters such as floods, landslides and droughts"

1.3 Limitation

- The study lament gaps in hazard research and paucity of long-term good data

CLIMATE CHANGE PROJECTIONS BY AVAILABLE LITERATURE SPECIFIC TO BHUTAN (contd)

2. Vulnerability and Adaptation Assessment Volume I, Technical Paper, 2011, National Environment Commission, Bhutan

2.1 The above report describes spatial patterns of monsoonal (June to September) temperature and precipitation and their changes over time, covering the period 1980 to 2069.

2.2 The report laments that on account of lack of complete set of observed data, the study had to resort to Precis-downscaled HadCM3 and ECHAM5 simulated data.

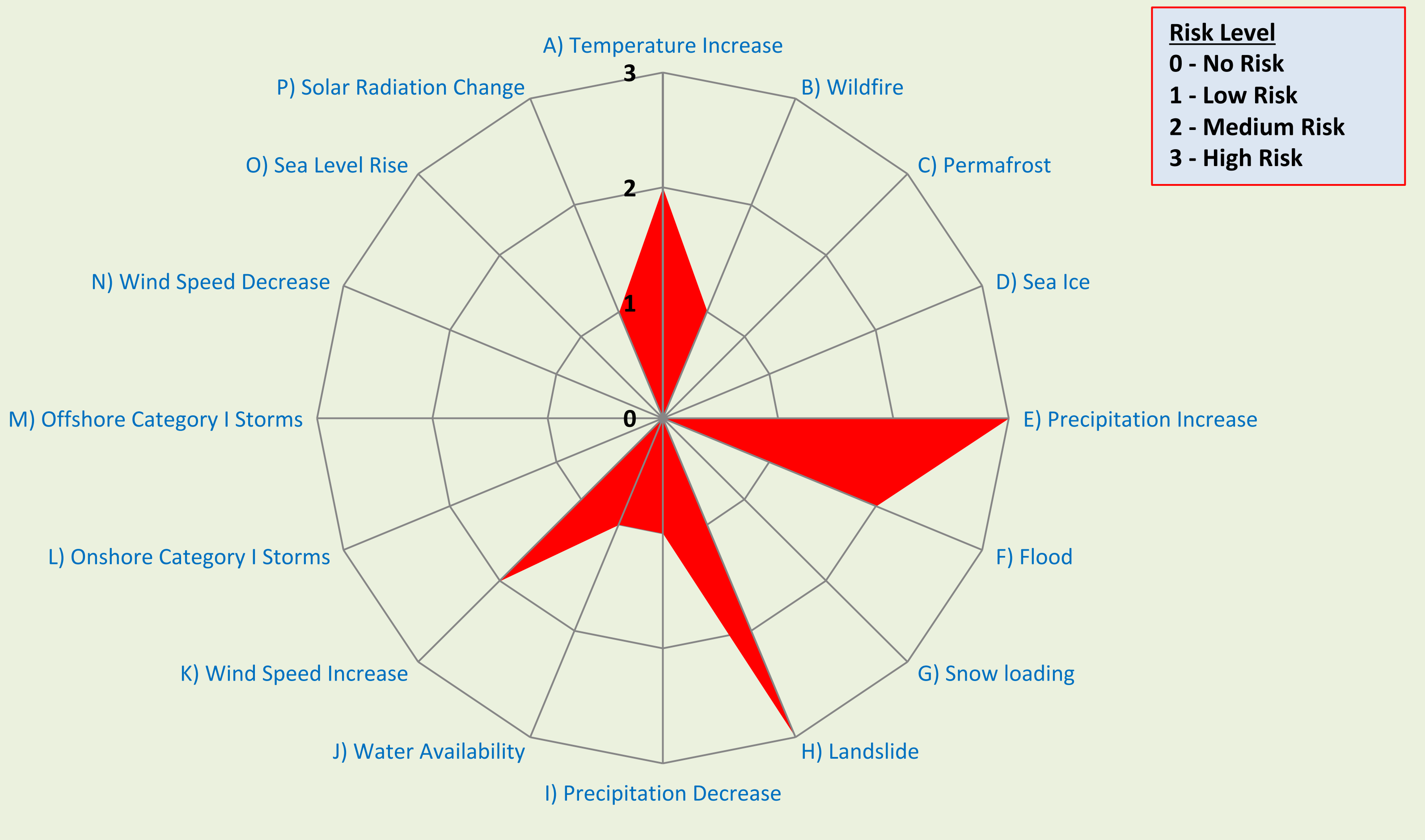
2.3 Two future time slices viz. 2010-2039 and 2040-2069 have been used to demonstrate the future expected changes in air temperature and precipitation on two seasonal (monsoon and winter) basis.

2.4 The spatial pattern of mean seasonal (monsoonal) temperature according to Precis-downscaled HadCM3/AIB scenario for Bhutan for the period 1980-2009 indicate a pronounced zonal pattern with temperatures increasing with latitude from south to north.

2.5 By the same scenario for the period 2010-2039, a migration of warmer temperatures northwards has been indicated. Mean seasonal changes in the southern districts of Bhutan (project area) are shown to become more tropical in nature with mean temeprature increases to ~ 24^{0}C to ~ 30^{0}C.

Synopsis of Project Risk Assessments under Climate Change
(Deothang-Nganglam Road Project)

(Courtesy: Aware^{TM} geographic data set) and as compiled for the project from the latest scientific information on current climate and related hazards together with projected changes for the future where available.



Climate Change Risk Adaptation Methodology in the Design of the Highway

1. Adaptation to Risks under Extreme High Precipitation due to CC

- (*The WMO guideline (WCDMP- No. 72) suggests as a pragmatic approach to check for trends for any specified period (regardless of cause) as trends provide the simplest component of climate change providing information on the first-order changes over the time domain considered.)*
- **Precipitation:** In the case of Deothang – Nganglam highway project, the first procedure was to conduct an analysis of annual daily maxima series of rainfall as recorded at Deothang Class A Met station. The met records of Nganglam was discarded as it contained too many anomalies besides being a Class C station.
- In spite of limited data in terms of years (16 years), a conventional analysis of block maxima annual daily precipitation was conducted to check for any trend per WMO's recommendation
- Processes involved: screening of data (Spearman's test to verify presence or absence of trend)→ data homogeneity to check for inconsistencies of the station record by double mass → fitting of frequency distributions for best fit distribution (lognormal, Log Pearson III and Gumbel Max) → and finally an EVA providing return levels for various return periods using Gumbel
- Limitations: The drawback of the conventional EVA is that the confidence that can be placed in the results is minimal as the length of the return period is substantially greater than the period covered by the available data

Climate Change Risk Adaptation Methodology (contd)

Case of Precipitation under CC

- With no discernible trend found in the block maxima series of max precipitation data, the CC adaptation recommendation made was in terms of factor of percentage adjustment per 1^0C rise in temperature in the design ARI or return period
- Factor of Percentage Increase per 1^0C of warming to apply to Extreme Rainfall

  (Source: Tools for Estimating the Effects of Climate Change on Flood Flow; A Guidance Manual, New Zealand)

	ARI (years)						
DURATION ▼	***2***	***5***	***10***	***20***	***30***	***50***	***100***
10 minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0
30 minutes	7.2	7.4	7.6	7.8	8,0	8.0	8.0
1 hour	6.7	7.1	7.4	7.7	8.0	8.0	8.0
6 hours	5.3	6.1	6.8	7.4	8.0	8.0	8.0
12 hours	4.8	5.8	6.5	7.3	8.0	8.0	8.0
24 hours	4.3	5.4	6.3	7.2	8.0	8.0	8.0

The upper limit of 8 per cent has theoretical support in that it is the rate of increase in the moisture-holding capacity of air as temperature increases. Studies have found that, at least in the extra-tropics and for a regional average, the 8 per cent increase agrees well with global and regional model estimates (*Pall et al, 2007*).

- From ICIMOD, projections for Eastern Himalayas as under:

  In 2020's → warming up by 1.4 ± 0.3^0C

  In 2050's → warming up by 2.5 ± 0.4^0C

  In 2080's → warming up by 3.8 ± 0.5^0C

Adjust Estimate of extreme rainfall % increase using mid range warming

Say, for 15 min, 10-year ARI, $P_{15,10\text{-}year} = 1.4 \times 7.89 = 11.05\%$ *increase*

Climate Change Risk Adaptation Methodology (contd)

Case of Flood Volume for Bhutan's Major Rivers (Specific Discharge Method)

- The drainage pattern of Bhutan is principally segregated into three hydrological regions and are tagged as basins I, II and III. These are main rivers flowing north to south, originating from perennial glaciated regions lying in the north of the country at altitudes over 7000 m.
- Besides the main basins, there are several sub-basins with north-south orientation, whose headwaters lie in the interior of the country and where glaciation has minimal influence. All others are east-west tributaries of the main drainages that contribute greatly to water budget of the country.
- A suitable reasoning to adoption of the specific discharge method for drainages above 1000 km^2 lies in the fact that as the basin size increases, storage or detention effects and unfamiliar dynamic flow effects dampen the peak flow in a non-linear relationship. It has been recognized that: - *As the catchment size increases, the specific discharge decreases.*
- Annual maximum discharges from gauged station records of major rivers were used; the extreme events as recorded due to GLOF and LDOF (detected outliers) were introduced in the maximum specific discharge analysis. A bootstrapping (Monte-Carlo type) simulation was propagated randomly to assuage the limited data series.
- The resulting empirical relationship $Q = 4.56\,A^{0.9125}$ was adopted for major rivers flowing through the project corridor.

Climate Change Risk Adaptation Methodology (contd)

Estimation of Design Floods for Minor Drainages, < 20 km^2

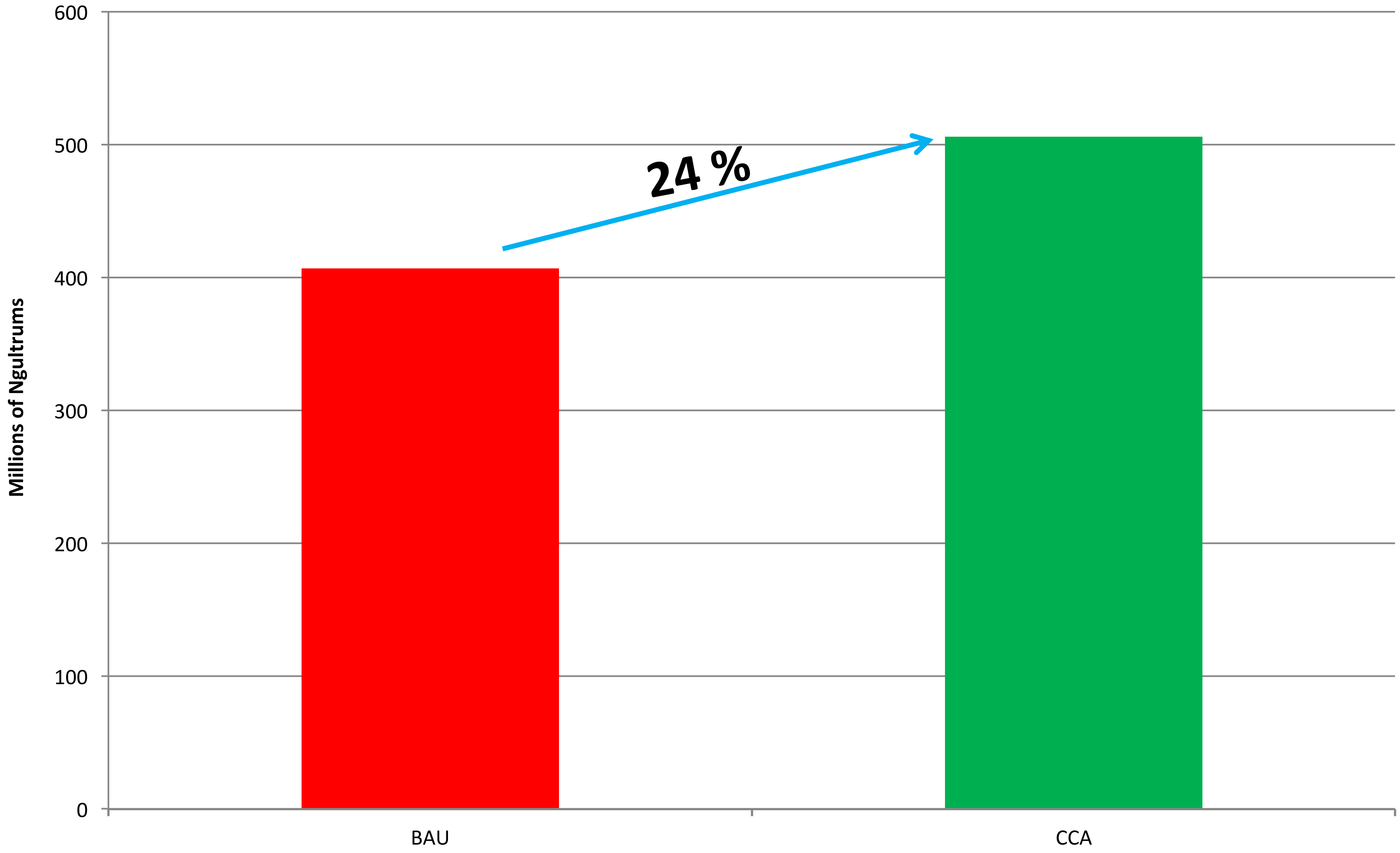
- suggested the use of the rational method for estimations of design floods using the extreme rainfall data adjusted by the factor of percentage shown earlier.
- Most climate change literature assume that it is likely under a changed future climate, where frequencies and intensities of extremes are likely to increase, that a 1 in a 50 year event could become a 1 in 20 or so year event in the future and in such a case the sizing of any structure is achieved by increasing the return periods to account for climate change rather than using a lower recurrence period.
- Thus it was instinct to recommend to adopt a higher ARI in the design of various components of the highway infrastructure although highway designs may justify a lower return period (e.g., 25- year or 50-year) in certain areas - balancing the greater risks affiliated with such design with engineering and economic considerations.

Category	Presently Applied ARI	Upgrade to ARI
Major Road	50 year	100 year
Cross drainage (culverts)	10 year	20 year
Kerb and Channel Flow	5 year	10 year

ADDITIONAL ADAPATATION MEASURES CONSIDERED BY THE HIGHWAY DESIGNERS TO COMBAT CLIMATE CHANGE RISKS

- Improvements in the concrete mix design
  - Recommended to be upgraded to M15 from M10
- Improvements in the Cement Mortar design
  - Recommended to be upgraded to CM 1:4 from CM 1:6
- RMM masonry
  - Use RRM instead of composite RRM/DRM
- Drainage
  - Trapezoidal instead of L-drains
  - Hume pipes upgraded to 1200 dia instead of 900 dia
  - More than the nominal 4 cross drains per kilometer of road length depending upon site conditions
- Adaptive Maintenance Management
  - Adaptive maintenance management that calls for incremental adaptation to be decided and implemented over successive short timescales (say for eg. every 5 years instead of 10) can provide advantage to manage climate change uncertainty iteratively, based on gradually increasingly reliable climate change data whilst reducing the risk to commit to highly expensive investment which could tune out inadequate.

BAU COST vs. CLIMATE CHANGE ADAPTATION COST



CHALLENGES AND LESSONS LEARNT

1. Methodological Issues

- We know that scientists simulate the climate on the computer and a large proportion of their work is devoted to improving and refining the simulations: Sadly, they do not teach us how to apply in practical circumstances in solid terms particularly when faced with a ToR that explicitly mentioned the identification of climate change risks and vulnerabilities of the project roads based on hydrological studies using climate projections for the project area.

2. Just 16 years of Data

- By many guidelines. at least a minimum of 30 years of record is recommended for a statistical analysis of rainfall-runoff for design discharge estimations. Unlike elsewhere where rainfall-runoff records exceeding 30 years or so have judiciously employed statistical techniques of observed rainfall and the immediate consequential runoff as the basis for their design discharge estimations, unfortunately this was not the case of Bhutan. In spite and very little confidence IDF and DDF curves were developed for use by the design engineers with recommendation to revise when data accumulates over time.

3. Decision Making under Circumstances of Great Uncertainty

- Adaptation to climate change necessitates a shift in existing design and planning paradigms, as the demands placed on transportation will require more robust systems that can cope with an increasingly extreme and volatile climate – *very easily said*

CHALLENGES AND LESSONS LEARNT (contd)

- By the WMO guideline →→ a pragmatic approach is to calculate trends for any specified period regardless of cause as trends are the simplest component of climate change and provide information on the first-order changes over the time domain considered. This implies that the physical mechanisms behind the detected trends remain unknown. But no discernible trend in the data could be identified. In fact a slight negative trend was discernible. So ????
- A program called the extRemes toolkit, an R-based, user friendly, interactive program for analyzing extreme value data is in the WMO guideline. The program provides for an introduction of a trend in the data series to produce a non-stationary output which loosely represents a future climate. But without an observed + trend, doubts were natural. If carried on with no trend introduced; the conventional stationarity outputs is produced which is refuted by climate change experts.
- The ultimatum was to seek more literature where elsewhere, others had coped with this dilemma. Therefore the climate change adjustment factor was adopted to provide a little higher confidence.
- Further, through discussions with project environmentalist and highway design engineers, additional adaptation measures in terms of upgrading design concrete mix, changing drainage profiles, increasing the cross drainages per kilometer and their sizing were thought as probable best practices for the project given the limited data and knowledge of climate change in the local context.

An Unassuming Recommendation

- There is no denying the fact that transport infrastructure has already in the past dealt with extreme events that caused interruptions, economic losses and loss of lives, whether stemming from natural hazards or human impacts. However, climate change is occurring throughout the world and some of the observed changes have established records in recent years.
- Scientific literature today on adaptations to climate change in infrastructure design are limited but progressively on the rise. Until such a time when concrete scientific recommendations are clear and disseminated, a consideration today is reassessment of current transport design policies and a climate change legislation that includes a mandate to organizations to carry out risk assessments and to develop climate adaptation strategies for a better “No Regrets” situation
- Such governmental efforts to a climate change policy will help to provide a positive basis for all stakeholders to identify their own risks and opportunities for action in a balancing bottom-up approach.

To End

- This extract from an ADB report aptly points to the difficulties of climate change adaptation planning: *(Technologies to Support Climate Change Adaptation in Developing Asia, 2014 Asian Development Bank, adbpub@adb.org)*
- '*Planned adaptation in response to or in anticipation of this impact can mitigate or prevent some harmful effects of climate change, and draw benefits from the more positive consequences. But there is a dearth of consistent, comprehensive information about the most recent developments in adaptation technologies and a lack of access to institutions and agencies that can facilitate technical and knowledge transfer. Adaptation practitioners are thus held back from developing a robust portfolio of hard and soft adaptation technologies*'

- *THANK YOU ALL*