Regional Seminar on Safe, Climate Adaptive and Disaster Resilient Transport for Sustainable Development
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Transport Infrastructure - Adaptation to climate change and extreme weather impacts

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Purpose of the presentation

Climate change adaptation to transport infrastructure

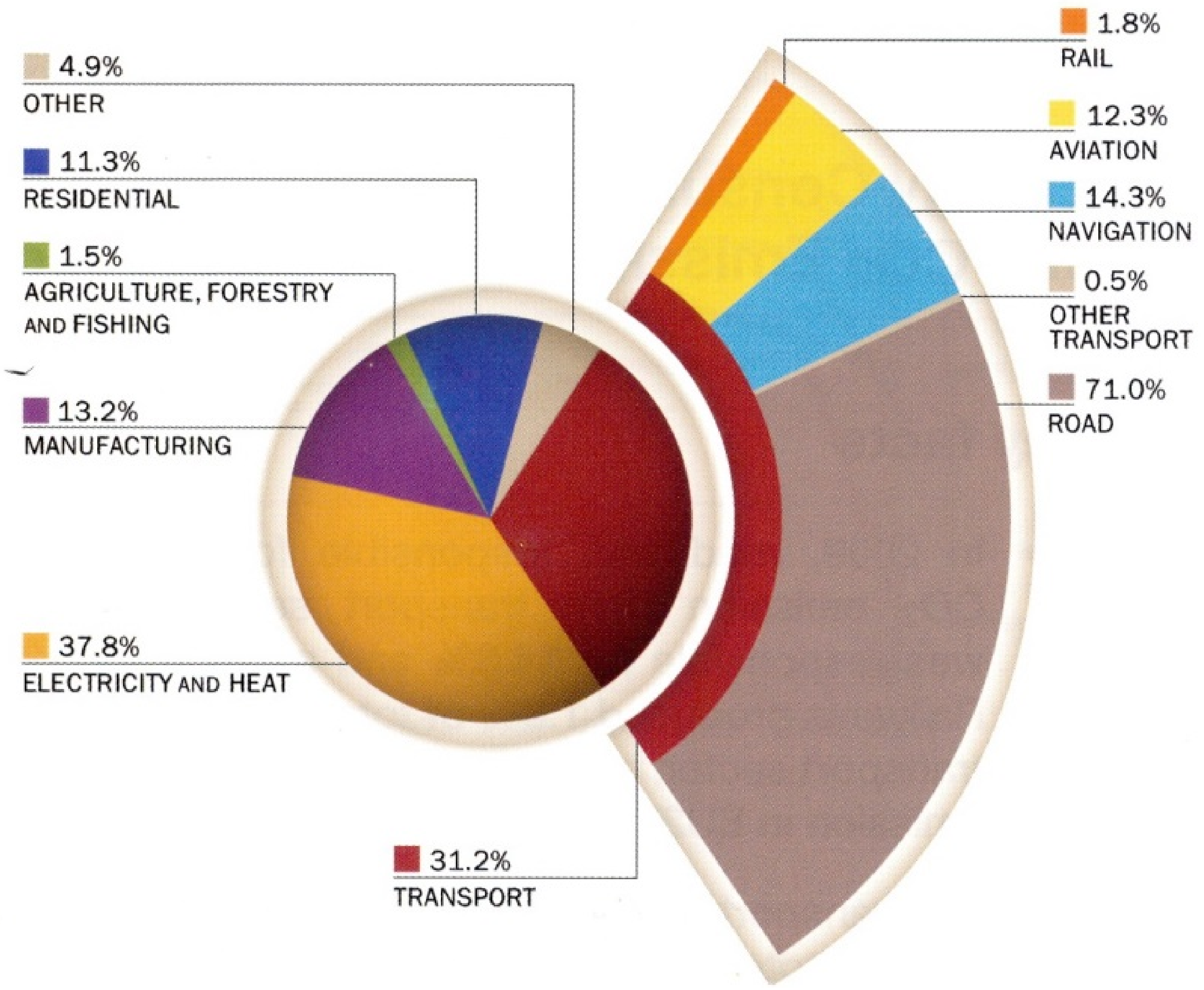
- Introductory observations – reality check
- Climate change impacts on transport infrastructure
- Adaptation in practice
- Climate change into infrastructure design practices
- Way forward
- Conclusions

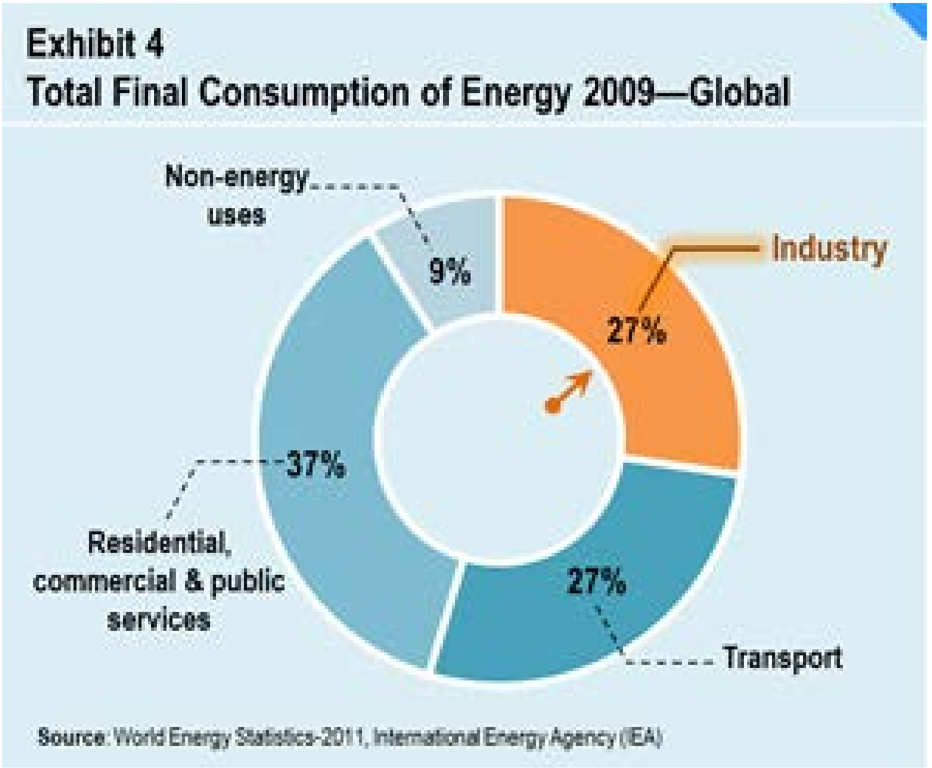
Climate change – reality check

- **The atmosphere and ocean have warmed**, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.
- The globally averaged combined land and ocean surface temperature data show a **warming of 0.85 [0.65 to 1.06] °C, over the period 1880 to 2012**.
- The rate of **sea level rise** since the mid-19th century has been larger than in the previous two millennia. During 1901 to 2010, global mean sea level rose by 0.19 [0.17 to 0.21] m
- It is likely that **the frequency of heat waves has increased** in large parts of Europe, Asia and Australia. There are likely **more land regions where the number of heavy precipitation events has increased** than where it has decreased.
- Concentrations of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) have all increased since 1750. In 2011 **the concentrations of these greenhouse gases exceeded the pre-industrial levels** by about 40%, 150%, and 20%, respectively.
- The largest contribution to total radiative forcing (driver of climate change) is caused by the **increase in the atmospheric concentration of CO2.**
- **Continued emissions of greenhouse gases will cause further warming…. Limiting climate change will require substantial and sustained reductions of GHG emissions.**

Source: IPCC, Climate Change 2013, Summary for Policy Makers

CO2 emissions from fuel combustion by sector and by mode



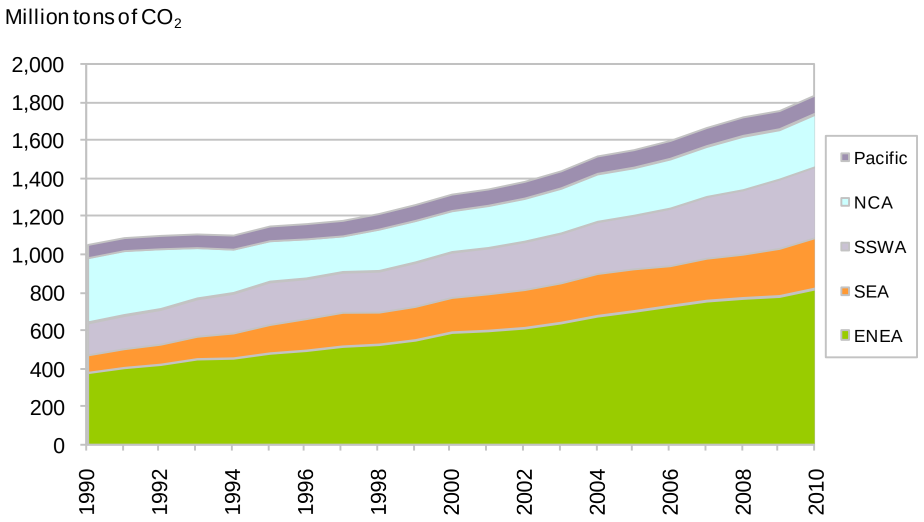


In 2010, emission from the road sector accounted for about 83.3% of total CO_2 emission from the transport sector of the AP region.

Source: *Source: International Energy Agency & International Union of Railways "Energy Consumption and CO2 Emissions*

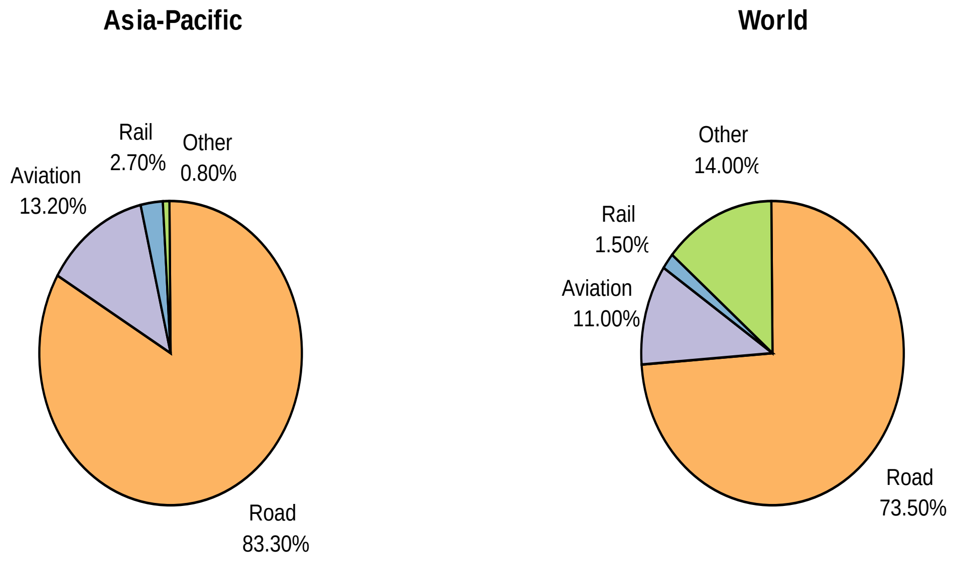
CO2 emission is on rise -
Asia is more dependent on road transport

CO2 emission in Asia-Pacific



Source: UNESCAP, SYB 2013

Energy consumption by mode



Improved efficiency in the transport sector can reduce GHG emissions from the sector

Transport and climate change

Transport sector contributes to as well as impacted by climate change

A case for mitigation

Train went off the track as the base material got
Washed away by the waters of a swollen river

A case for Adaptation

Climate change effects affecting the transport sector

Actual or expected climate change effects and their severity:

- Rapid rise in average temperature – faster than average global rate of warming (1.8 - 4^{o} C by the turn of the century)
- Change in rainfall pattern – decrease in winter rainfall and increase in summer rainfall -
- More frequent extreme weather events – heat waves, more intense rainfall, increased cyclone intensity - flooding
- Rise in sea-level (e.g., about 40 cm in Bangladesh) – inundation of infrastructure, storm surges

Climate change impacts on transport infrastructure – how much costs are imposed?

Impacts on transport infrastructure – Cost implications

- Increased operation, maintenance, repair and rehabilitation costs of transport infrastructure
- New transport infrastructure – higher costs because of higher climate adaptable design standards and construction materials
- Change and/or modification of existing hydraulic structures and flood protection measures, additional new hydraulic structures or flood protection measures – increased cost (e.g. 13 km flood protection wall around Don Mueang airport perimeter, Bangkok)
- Disruptions in transport network operation and services (Closure, limited operations, restrictions etc.) – affecting normal economic activities and losses thereof

Impacts of climate change - some estimated costs on transport infrastructure

- **European Union:** Weather induced costs for road transport – estimated 1.8 b Euro per year
- **U.S.A.:** To spend about 20% more on highways and aviation infrastructure maintenance or about $15 b per year for the present level of service
- **DCs:** Between 2010-50 the infrastructure sector represents an estimated $15 billion–$30 billion a year. Roads and urban infrastructure account for most of this estimated adaptation cost. More than 50% of this cost is expected to be incurred in South and East Asia and the Pacific. (WB, 2010)
- **Bangladesh:** A WB study of 2014 estimates – increased salinity in coastal areas would cause increase in road maintenance expenditure by 252%;

Based on 2007 Sidr Cyclone damage estimates – USD 239.5 m additional damages to road infrastructure due to increased storm surges (WB, 2010); affected length of highways: 3,315 km; affected length of embankment: 13,996 km (by 2050).

Source: Different published materials

Potential impacts of climate change

- More frequent/severe flooding of transport infrastructure due to more intense rainfall, sea level rise and storm surge
- Increased number and magnitude of storm surges and/or sea level rise can shorten transport infrastructure life
- Higher maintenance and construction costs for roads and bridges due to rise in temperature and exposure to storm surge
- Increased thermal expansion of bridge joints and pavements, potentially causing degradation, due to higher temperatures and heat waves, corrosion of RCC
- Asphalt degradation and shorter replacement cycles
- Culvert and drainage infrastructure damage (intense rainfall, storm surge)
- Derailments and longer travel times due to rail buckling during extreme hot days
- Disruptions in air traffic, and reduced aircraft performance (range and payload)
- Disruptions in port operations and damage to navigational infrastructure

Transport systems – necessity of climate change adaptation

- Failure to adapt would lead to accelerated deterioration of costly transport assets
- Service disruption of unknown duration and consequences on economy and people's lives
- Huge new investment to rehabilitate/replace transport infrastructure

Adaptation to climate change

Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (UNFCC)

Adaptation to climate change

Four main adaptation strategies:

- Updating design and construction standards and materials to ensure that future infrastructure is more resilient to anticipated climate and extreme weather events (technical solution) – many countries
- Asset management practice – based on climate event related risk assessment (e.g., U.K., New Zealand)
- Risk mapping of climate stress vulnerability of transport infrastructure – future investment should be guided by such risk mapping – many European countries
- Adoption of a broad network-scoped strategy driven transport planning approach – (Netherlands, Horizon 2020)

Climate adaptation in practice

Seven broad areas may be identified

- Climate adaptation strategies and policies including sectoral strategies and policies at the national level
- Climate change vulnerability and risk assessment
- Long range transport planning and land use
- Integration of climate change into infrastructure design practices
- Maintenance and operation
- Asset management
- Research (- nature, magnitude and extent of impacts and their remedial/adaptation measures)

Adaptation in practice - examples

- Climate adaptation transport strategies and policies at the national level – Canada, Denmark, UK, Netherlands, New Zealand, Norway, USA
- Climate variability and change risk assessment (Denmark) – have developed systematic methods to assess and address risks
- Changes in long range planning and land use processes – UK, approval of important national infrastructure projects require consideration of climate change effects in planning of location, design, and operation
- Integrating climate change into design standards: KEC, ROK (200-year return period in place of 100-year, Minimum 2m freeboard etc)
- Maintenance and operation: Improving emergency plan, safety warning, increased inspection etc. (Denmark; KEC, ROK)
- Asset management: UK, New Zealand
- Research and outreach: Many European countries, USA

Climate adaptation into national transport strategies and policies - international experience: USA

Three key policy reforms

- **Risk mapping** – climate stress vulnerability of major transport infrastructure – should be used to guide present and future investment; the private sector in turn should make their own investment decisions reflecting decisions on public investment
- Adoption of a formal **asset management** approach incorporating risks due to expected climate related stresses
- **Update planning and design standards** in order to ensure that future infrastructure capital is more resilient to anticipated climate change and/or extreme weather events

Long range planning and land use

UK - National Road and Railway Networks National Policy Statement (2013) – under Planning Act 2008

Approval of important projects require consideration of climate change effects in planning of location, design, and operation; requires consideration of high impact to those elements that are critical to safe operation of the infrastructure

Netherlands – The Delta programme: Delta Act 2012 requires yearly plan to protect from high flooding and ensure supply of fresh water; deals with uncertainties – based on Delta scenarios considering account socio-economic trends (popn, urban, agrl, econ, nature) and climate change (summer and winter precep, sea rise); the Annual Programme identifies measures and projects to adapt physical systems as well as spatial planning strategies to proactively manage flooding

Climate change into design practices - international experience – Republic of Korea

Measures taken by Korea Expressway Corporation (KEC) – Road sector

Strengthened Design Rainfall Generation Frequency: In mountainous areas drainage facilities be built for a 100-year event; previously 25-50 years; in other areas 20 years, previously 10 years

Increased safety factor for slope stability: Increased from 1.1 to 1.2

Improved function of drainage facilities: KEC has made improvements to its design criteria to improve the ability of drainage facilities to collect and carry water.

Increased concrete strength: To protect structures from salt damage caused by increased use in de-icing materials, concrete strength was increased from 24 mega pascals (MPa) to over 30 MPa. This also helps to protect the structures against frost damage.

Employed bridge design countermeasures: New bridges designed for a 200-year return period. Increased the minimum freeboard from 1 to 2 meters; increased bridge opening sizes and flow capacity by raising required span lengths. Relocating bridge piers and foundations outside of main channels. Also taking steps to adapt in-service bridges at low elevation, by either reconstructing them or raising their heights by 1 to 3 meters.

Adapted transport infrastructure - examples

MRT access, Bangkok

Flood protection wall

Courtesy: KEC, ROK

Maintenance and operation

<u>Warning system to avoid secondary or collateral impacts of climate related events.</u> Some developed countries have installed warning systems in climate sensitive areas to ensure weather related safety and avoid such incidents

- Demark
- KEC in ROK
- Japan

Climate change/extreme weather impacts on transport infrastructure - Bangladesh

Bangladesh is among the most vulnerable countries to climate change; predicted vulnerability to increase due to sea level and temperature rise, higher and more intense rainfall, increased frequency and severity of cyclones, and increased salinity

- Increased flood and erosion damage to road and rail infrastructure and their embankment
- Accelerated wear and fatigue damage to transport infrastructure due to extreme temperature
- Increased obstruction by debris after flood and storm surge
- Salinity impact on infrastructure in coastal areas including corrosion of RCC structures
- Frequent land slides due to intense rainfall in hilly areas -
- Localized ground subsidence causing damage to infrastructure

Coastal climate resilient infrastructure project (CCRIP) - Bangladesh

- Bangladesh is one among the first developing countries which prepared a national strategy and action plan:

  Bangladesh Climate Change Strategy and Action Plan 2009

Two funds were set up, one using government resources (BCCTF) and the other using donor resources (BCCRF).

- Due reflection in the current Sixth Five Year Plan 2011-15
- Implementing Coastal Climate Resilient Infrastructure Project (CCRIP); One of the objectives:

Enhance security and safety of rural infrastructures through development of rural infrastructures up to climate proofing standards which includes enhanced resilience to present climate effects plus forecasted future climate change impacts.

Bangladesh - adaptation coastal roads

- Crest level raised 200 mm above A1B scenario sea levels in 2034.
- Surface material all concrete with minimum thickness of 150 mm with adequate reinforcement.
- Pavements to be thickened sand aggregate. Sub-base to be 0.25 meters wider than overlying layer.
- Embankments additionally strengthened on roads in flood areas with either concrete or brick work.
- Cross drainage structures increased as necessary with full width drainage layer in sub-base. (minimum 2 per km).
- Need for larger culverts assessed.
- Strengthened abutments and approaches to bridges and culverts.

Source: Preparing Coastal Towns Infrastructure Improvement Project, Vol 4., Annex – Climate Change Assessment and Strategy, ADB, Japan Fund for Poverty Reduction, Gov. Of Bangladesh 2013

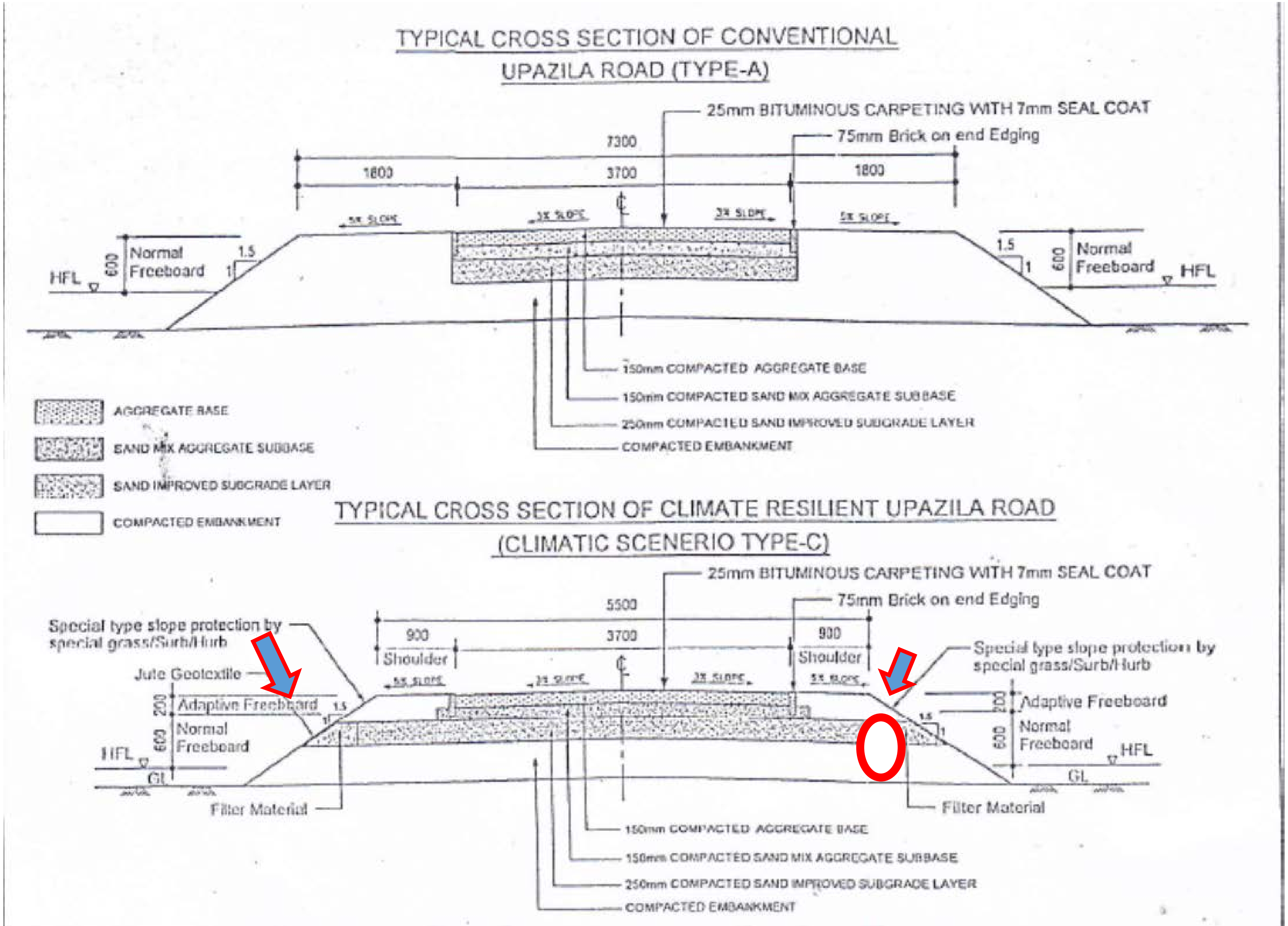
Note:A1B represents a mid-range emission scenario for the future global emission of Greenhouse gases. A1B makes assumptions about future growth and development of human activities during the next century. It was used for the IPCC climate change assessments in 2007.

Drainage and flood control:

- Existing drains rehabilitated and capacities enhanced to 2050 projections – dredging, re-profiling, lining, etc., as appropriate.
- New drains constructed to same capacity, including reinstating and enhancing natural drainage channels, etc., wherever feasible.
- Runoff detention capacity introduced wherever feasible.
- Materials selected and construction quality monitored for increased durability, because of longer inundation periods, wastewater risks, etc.

Courtesy: LGED

Conventional and climate resilient Upazila road design in Bangladesh



Source:
CCRIP Project

Comparative design features

Conventional Road Design	Climate Resilient Coastal Area Road Design
Road embankment - 60 cm normal FB above highest flood level	Raised embankment up to 80 cm above highest flood level; additional 20 cm adaptive FB
Drainage structures are provided based on present scenario	Adequate drainage structures considering added run-off; additional FB for bridge design considering sea level rise
Drainage layer in road sub-grade/sub-base is normally absent	Pavement design incorporates a full drainage layer
Widths of sub-base and base layer are the same	Sub-base layer at least 0.25 m wider than base
Concrete pavement – sand aggregate sub-base is not normally provided	Concrete pavements will have sand aggregate sub-base
RCC pavement is not normally considered	RCC pavements will be provided in vulnerable sections prone to tidal surges
Normal slope protection; grass turfing and limited RCC palisiding	Bio-engineering type of slope protection with conventional RCC palisiding to protect from tidal surge
Stage construction is not practiced	Stage construction in case of excessive high road embankment

Way forward – national level

Four strategies:

- **Planning:** Climate change impacts are considered in national level transport planning, sectoral planning and project development processes to protect national investments
- **Assessment** of climate change related impacts on existing infrastructures and consideration of appropriate adaptation measures
- **Asset management:** Climate variability and change impacts are duly considered and incorporated in transport asset management systems
- **Making planning and decision making tools available:** Tools, case studies, good practices, guidance, new design standards and outreach activities including climate considerations into transport decision-making as well as in asset management

Way forward – individual project

- Use of best possible information to assess all possible environmental risks including from climate variability and change in the locality
- Impact assessment - Assessment of risks/stress that a particular infrastructure is expected to withstand (model, construct scenario)
- Adaptation assessment - Consideration of alternatives for climate change proofing including the possibility of retrofitting at a future date; risks, costs and benefits
- Retrofit/modify existing structure – new structure, use updated design standards
- Implementation
- Monitoring and evaluation of adapted measures

Planning and design of adaptation measures -

Transport infrastructure are **highly diversified** in terms of what will be affected (e.g. airports, seaports, highways or inland ports) and how they will be affected. Considerable differences exist among regions due to specific local characteristics.

Each region has its **own set of vulnerabilities and risks**, underlines that when dealing with adaptation to climate change

- While effects are global, their nature, extent and magnitude are localized – requiring locally planned and designed adaptation measures
- Developing Countries need to develop their own capacity and R&D facilities on climate change adaptation

Fundamental Research

- Identification of vulnerable infrastructure and assets
- Identification of opportunities for adaptation of specific facilities
- Understanding changes in the life span of facilities caused by climate change
- Understanding the modes and causes of failure
- Assessing the risks, costs and benefits of adaptation
- Models and tools to support planning and decision making
- Monitoring and sensing

Source: Adapted from Meyer

Applied Research

- Planning and environmental decision making
- Design standards and practices
- Construction, Maintenance and Operations practices
- Renewal and rehabilitation
- New infrastructure to support mitigation measures
- Best practices
- Long-range planning related to transportation and land use
- Influencing of land use decisions, and
- Funding of adaptation

Conclusions

- Increased environmental stress/impacts due to climate change and/or extreme weather effects – a reality that we have to live with
- Adaptation into the transport sector should take place at the national, sector, and project levels. Each level has a specific role to play in addressing planning, budgeting, and community-level vulnerability issues.
- Consideration of climate impacts and adaptation should be integrated into the planning, policies, operations and programmes of transport agencies in order to ensure that transport infrastructure, services and operations remain effective in current and future climate conditions
- Asset management – accelerated deterioration of current asset values due to climate change impacts should be minimized
- Change in current transport planning approach - Adoption of a broad network-scoped strategy driven transport planning approach taking into consideration of regional ecosystem-based assessments and analysis

Thank you