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Impacts and Adaptation Requirements of Road Networks

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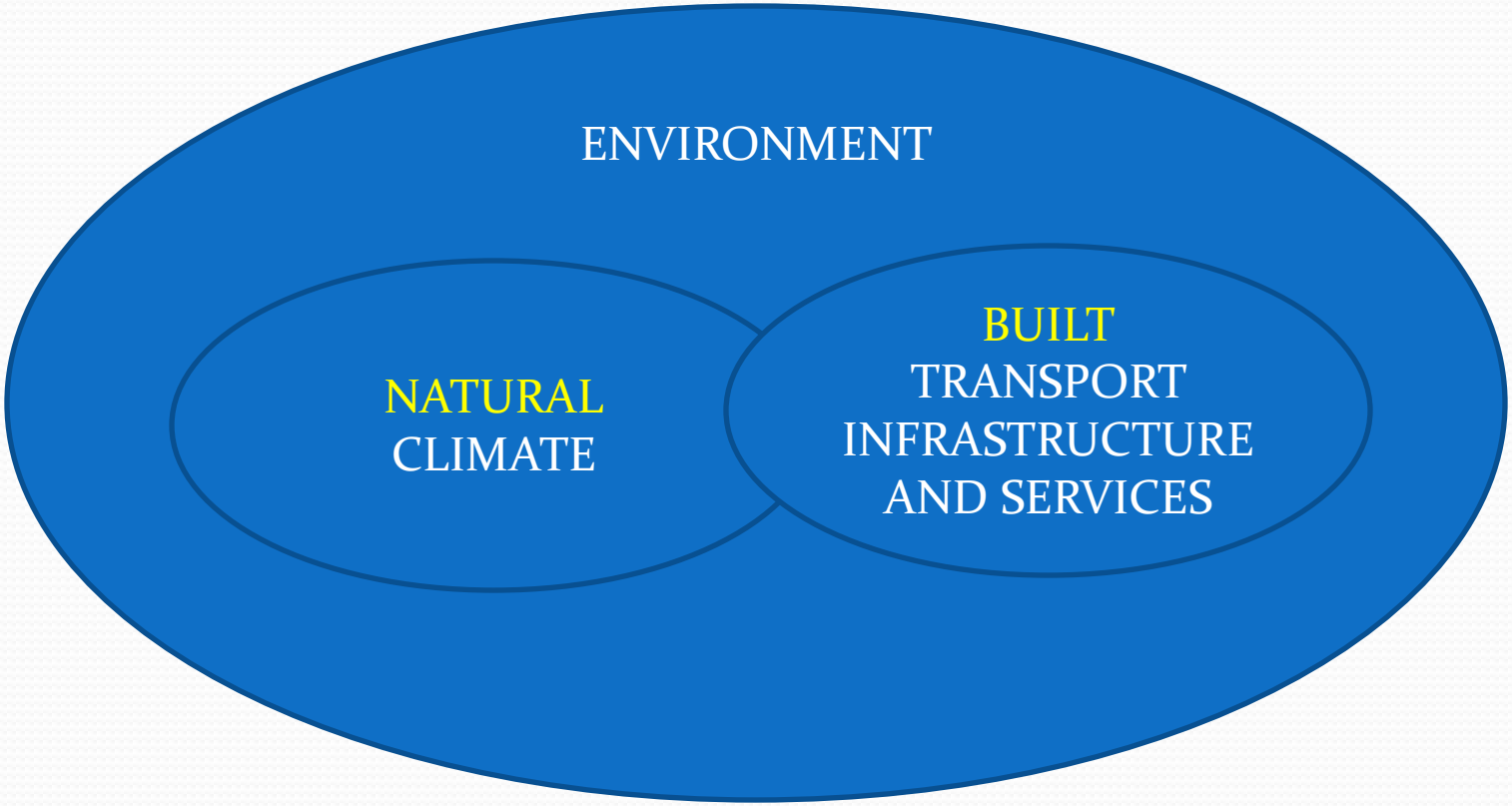
Interaction of Climate and Transport



Why Study Climate Change Impacts on Road Transportation?

- Affects the **safety**, **operation**, and **maintenance of road transportation infrastructure** and **systems.**

…affects all road network users!

Categorization of Impacts on Road Transportation Networks

- Infrastructure
- Operation and maintenance
- Direct
- Indirect
- Reversible (short-term)
- Irreversible (long-term)
- Local level
- International level

Main Impacts on Road Network

- Damage to road infrastructure through deterioration, deformation and subsidence (change in materials).
- Disruption of the network (rain, snow, high temperatures).
- Accessibility.
- Flooding from rivers, seas and inadequate land drainage.
- Severance of routes by erosion, landslides and avalanches.
- Damage to roadside infrastructure by high winds.
- Road safety (frequency and severity of accidents).
- Failures of “just in time” supply chains, most importantly food supplies.

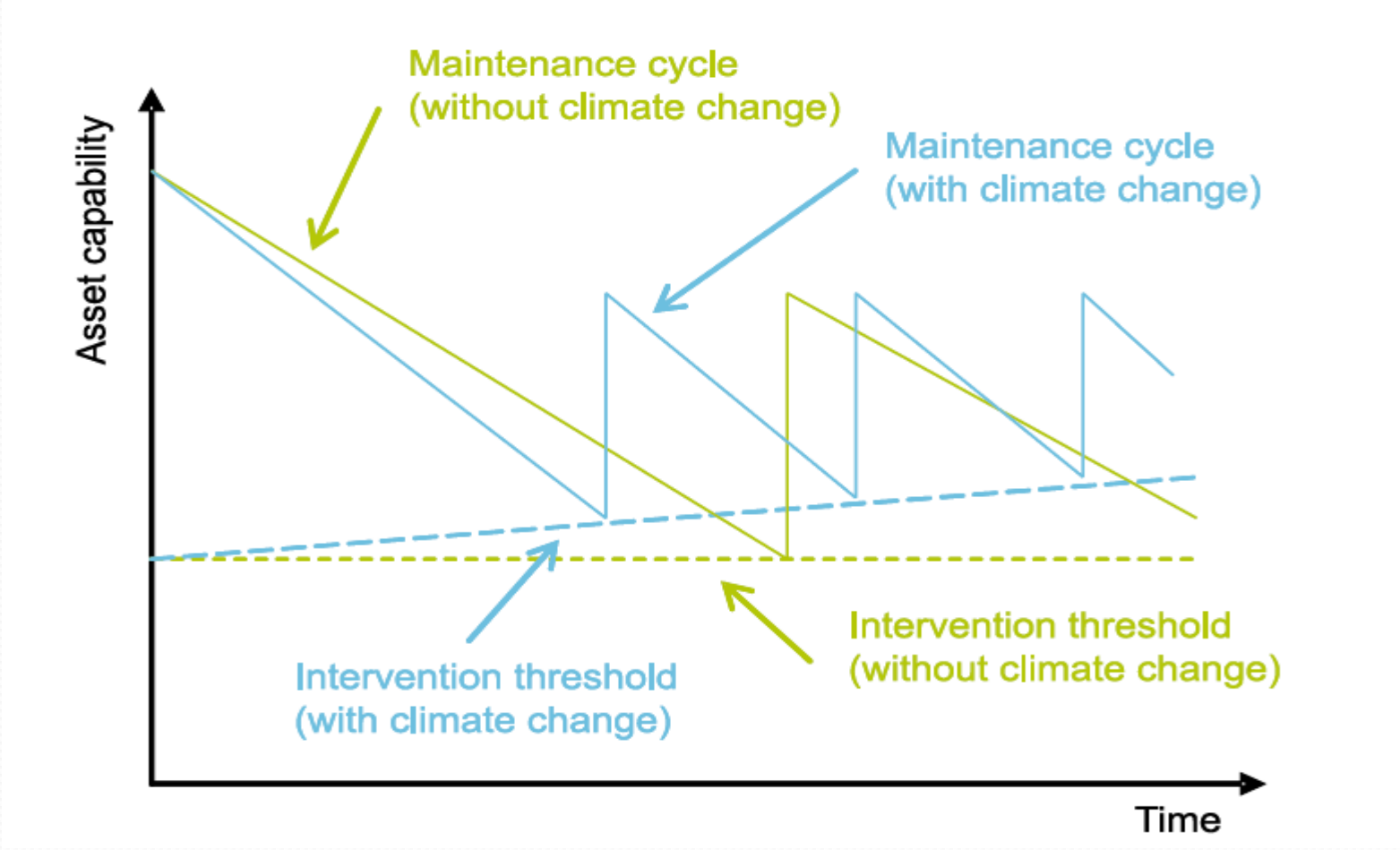
Temperature

- Pavement performance
- Frost damage (including freeze-thaw cycles and frost heave)
- Thawing of permafrost
- Milder winters
- Sea level rise

Precipitation

- Infrastructure damage and operations disruptions due to increased storm intensity.
- Flooding
  - Bridge / culvert capacities reduced or exceeded, causing upstream flooding to occur
  - Overtopping problems of structures
  - Scour problem of structures, especially bridge piers and abutments
  - Erosion of roads and embankments
- Surface water drainage problems.
- Erosion of roads and bridges.
- Slope failures, landslides and avalanches.

Impact on Road Network Maintenance



Source: UK Agency Climate Change Adaptation Framework (2009)

Indirect impacts

- Economic
- Environmental
- Demographic
- Spatial planning

Four key questions

- How important are the anticipated changes in climate?
- Can we anticipate them with confidence?
- What information is useful to transportation decisions?
- How can decision makers address uncertainty?

Approaches to Incorporate Climate Change (1)

- **Risk assessment approach**

– *Exposure:* What is the magnitude of stress associated with a climate factor and the probability that this stress will affect a transportation segment or facility?

– *Vulnerability:* Based on the structural strength and integrity of the infrastructure, what is the potential for damage and disruption in transportation services from this exposure?

– *Resilience:* What is the current capacity of a system to absorb disturbances *and* retain transportation performance?

– *Adaptation:* What response(s) can be taken to increase resilience at both the facility (e.g., a specific bridge) and system levels?

Source: Impacts of climate change and variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.7, 2008

Approaches to Incorporate Climate Change (2)

- **Planning timeframes**

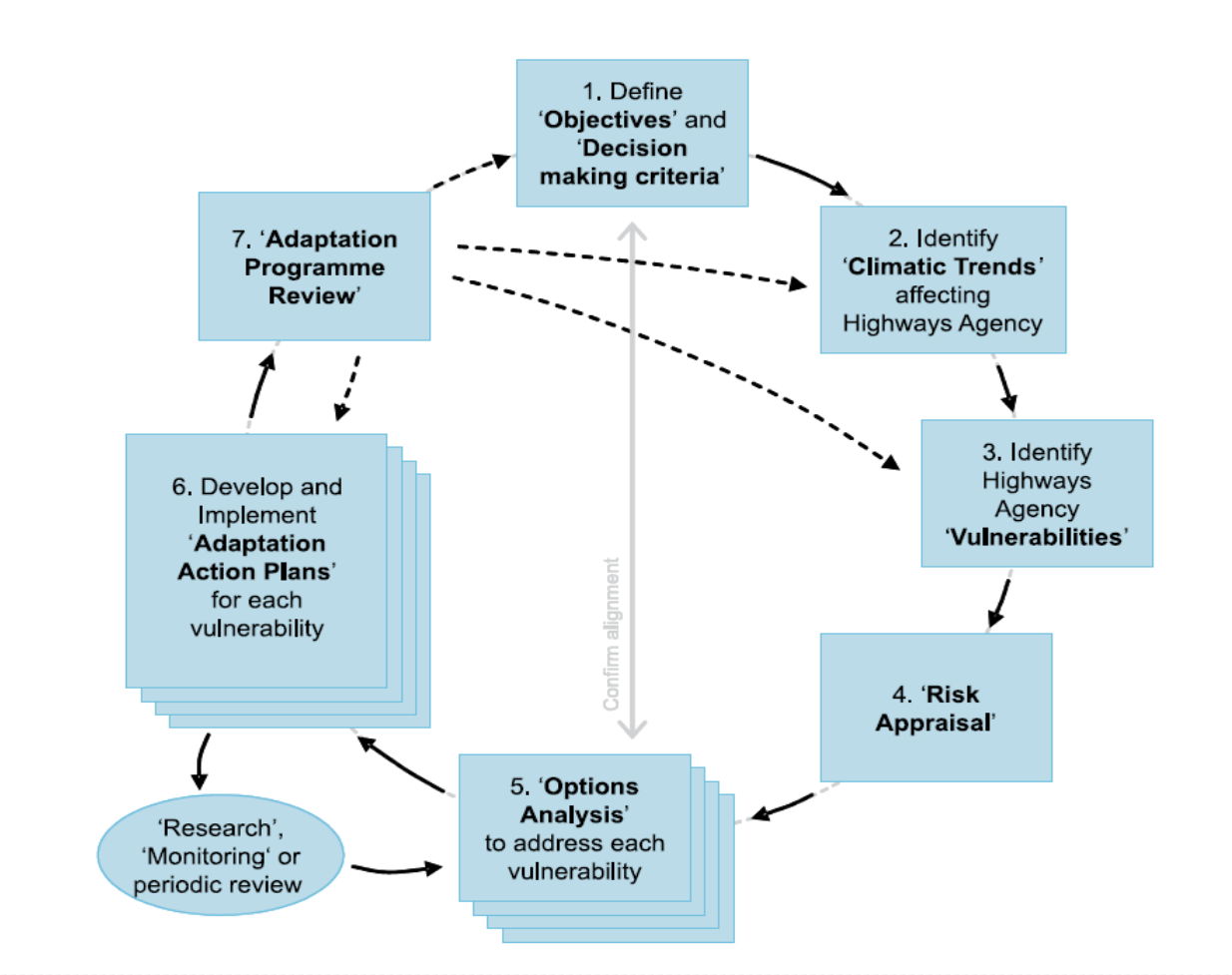
  Need to consider incorporating longer-term climate change effects into planning processes

- **Adaptation Strategies**

  What adaptation strategies are employed, and for which components of the system, will be determined considering the significance of specific parts of the network to the mobility and safety of those served, the effects on overall system performance, the cost of implementation, and public perceptions and priorities.

Source: Impacts of climate change and variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.7, 2008

UK Highways Agency Adaptation Framework Model



International Action

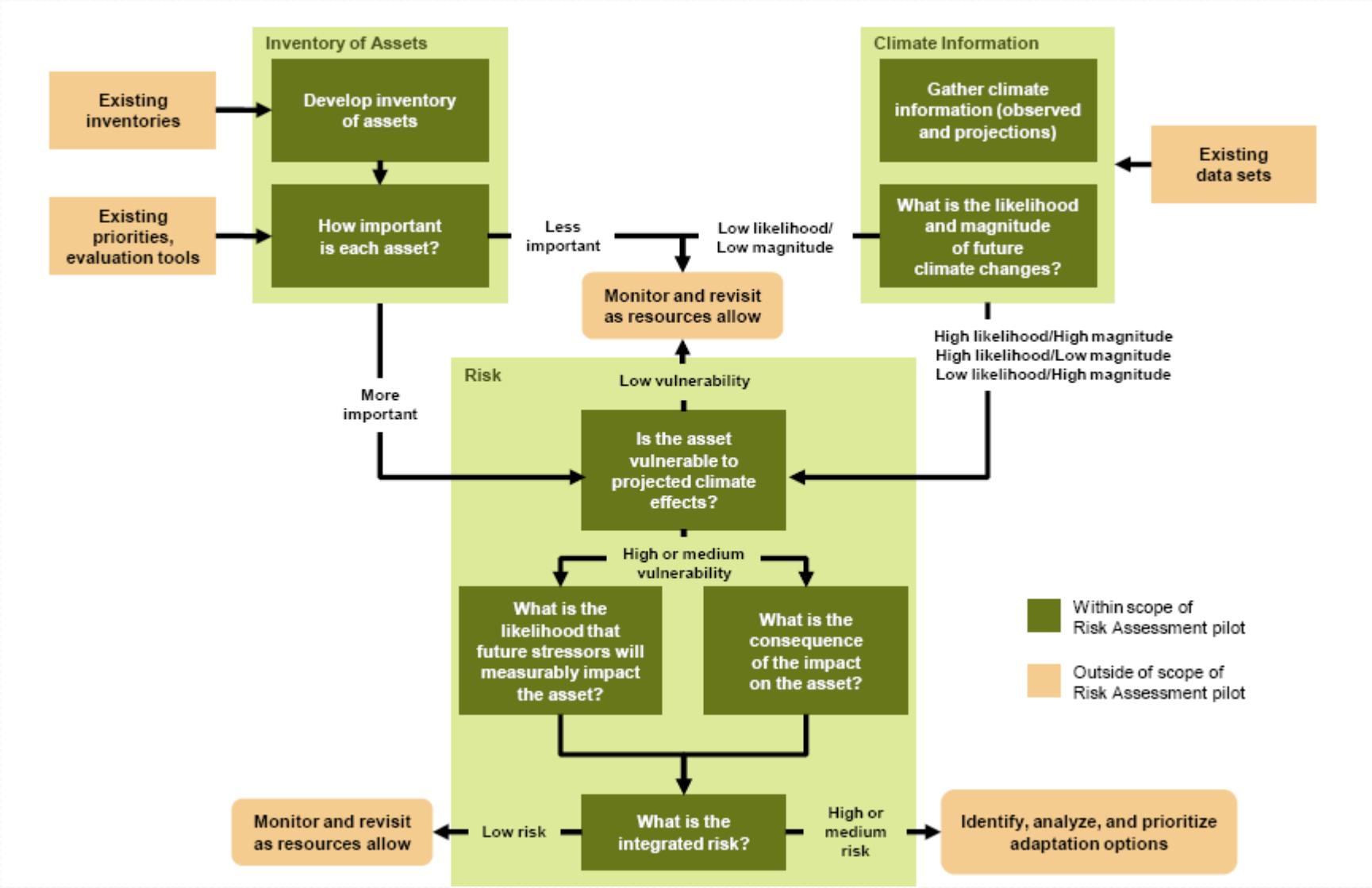
Country	Action to Adapt to Infrastructure to Climate Change Impacts
Australia	• Infrastructure Australia identified adaptable and secure water supplies to cope with climate change as one of seven key objectives. • Established a *Climate Change Adaptation Infrastructure Project*, which includes developing a standard 'climate change adaptation system for organisations'.
Canada	• Infrastructure Canada considers adaptation in its funding programmes. • Applicants to the Canadian Strategic Infrastructure Fund are required to demonstrate how their project addresses climate change impacts and adaptation and may be required to take certain measures to address these issues.
Denmark	• Road regulations and railway standards are being/will be reviewed and revised with consideration of expected climate changes. • The Danish Environmental Protection Agency published guidelines in 2007 in order for municipalities to take climate change into account in connection with construction and operation of sewage systems and sewer renovation.
Japan	• Issuing a series of documents on practical guidance on strategic climate change adaptation planning.
New Zealand	• National Infrastructure Plan (2010) identified the impacts of climate change as one of the long-term key trends that need to be addressed.
USA	• The Council on Environmental Quality has issued Implementing Instructions to be used by the Federal Government in climate change adaptation planning. • This includes Federal adaptation planning to address the effects of climate change on Federal infrastructure assets.
USA, California	• Established infrastructure working group to analyse the impacts from climate change on its infrastructure and strategies to adapt it.

USA Experience- Conceptual Model Pilot

- Conceptual Risk Assessment Model piloted by State Departments of Transportation (DOTs) or Metropolitan Planning Organizations (MPOs) selected by the Federal Highway Administration (FHWA).
- Consists of three primary components:

1. Develop inventory of assets
2. Gather climate information
3. Assess the risk to assets and the transportation system as a whole from projected climate change.

FHWA Conceptual Pilot Model Structure



FHWA Conceptual Pilot Model Steps

1. **Develop inventory of assets**
   - Asset Inventory and Prioritization
   - How Important is Each Asset?
2. **Climate information**
   - Gather Climate Information (from historical/projected data)
   - What is the likelihood1 and magnitude of future climate changes?
3. **Assessing risk**
   - What is the vulnerability of the asset to projected climate change?
   - What is the likelihood of a particular impact resulting from a defined set of stressors?
   - What is the expected consequence of the impact on society?
   - What is the integrated risk of climate change to the asset?
4. **Identify, Analyze, and Prioritize Adaptation Options**
5. **Monitor and Revisit as Resources Allow**

Classification of Risks to an asset according to categories of Likelihood and Consequence

Level	Likelihood
A	Remote
B	Unlikely
C	Likely
D	Highly Likely
E	Near Certainty

ASSESSMENT GUIDE

Likelihood	a	b	c	d	e
E	M	M	H	H	H
D	L	M	M	H	H
C	L	L	M	M	H
B	L	L	L	M	M
A	L	L	L	L	M

Consequence

RISK ASSESSMENT

High (Red)
Unacceptable. Major disruption likely. Different approach required. Priority management attention required

Moderate (Yellow)
Some disruption. Different approach may be required. Additional management attention may be needed

Low (Green)
Minimum impact. Minimum oversight needed to ensure risk remains low

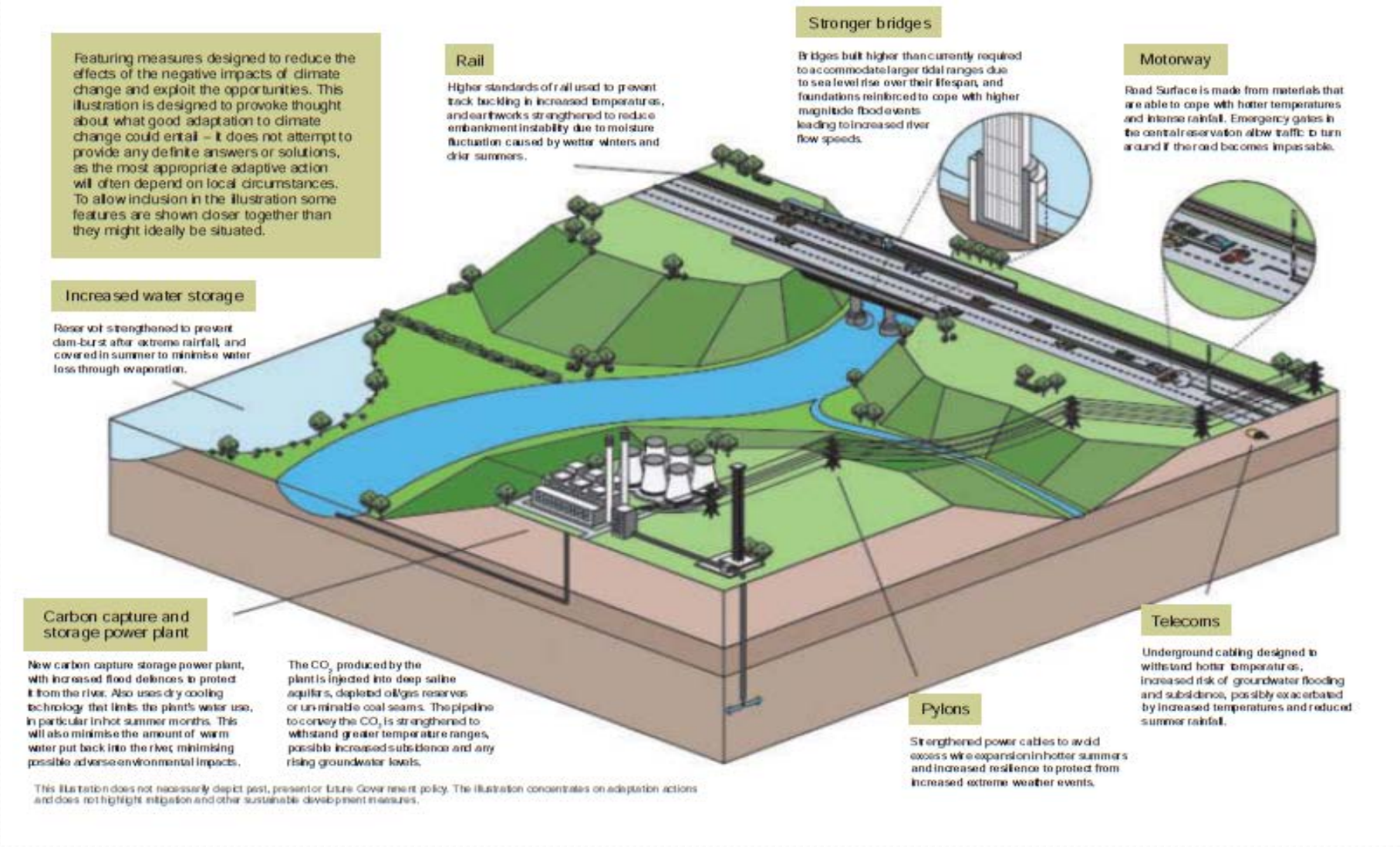
Level	Schedule	and/or	Cost
a	Minimal or no impact		Minimal or no impact
b	Additional resources required; able to meet		<5%
c	Minor slip in key milestones; not able to meet need date		5-7%
d	Major slip in key milestone or critical path impacted		7-10%
e	Can't achieve key team or major program milestone		>10%

USA Experience-New York State Department of Transport

- Established “Adapting to Climate Change Working Group”, recommending:
  - Planning strategies can best be developed within a consistent set of adaptation assessment guidelines
  - Adoption of risk-based management approach
  - Climate change adaptation can be most cost-effective when incorporated into infrastructure during replacement and rehabilitation.
  - Develop “vulnerability inventories” of a particular region.
  - Monitoring and reassessment are critical components of any climate change adaptation plan.
  - Training for staff for climate change adaptation.

Good Practices & Adaptation Measures

Measures to reduce Negative Impacts



Source: Climate Resilient Infrastructure: Preparing for a Changing Climate Presented to Parliament HM Government, May 2011

Design Issues

- Adaptation needs will evolve over time as climate science, impacts, technological advancements and adaptation strategies are further developed.
- State-endorsed climate change scenarios should be used, with updates.
- Design criteria should take into account the statistically non-stationary probabilities for hydrologic processes and other climate variables.
- For road surfaces and bridge expansion joints, new heat thresholds may need to be considered.
- Program and project designs should vary according to the expected implementation schedule and expected useful lifetime of structure or project, because the appropriate design should be for the climate variables and impacts expected at the date of implementation and beyond.
- Designs for rehabilitation and replacement should include climate adaptation planning, rather than being simply replacements of existing designs.

Pavement Performance

- Development of new, heat resistance materials.
- Sealing of cracked and distressed areas.
- Removal of roadside vegetation.
- Use more rut-resistant and/or stripping-resistant resurfacings.
- Surface dressing and micro-surfacings, especially with chippings with higher reflectivity.
- Stabilisation of unsealed pavements.

Frost damage, freeze thaw cycles and frost heave

- Keep road drainage in good condition.
- Use of insulation in the road prism.
- Manage vehicle numbers using the road.
- Apply axle load restrictions where necessary.
- Use of different types of passive refrigeration schemes, including thermosiphons, rock galleries and cold culverts.
- Installing steel grids in the road structure.
- Raise carriageway out of snow field.

Permafrost

- Increase vegetation/forest cover to protect permafrost.
- Good drainage, similar to those recommended for drainage related problems.
- Increase thickness of road embankment.
- Map and monitor of the permafrost areas.
- Excavate frozen icy material and replace with thaw-stable fill.
- Use open graded rock fill in embankments to improve heat transfer.
- Install insulation into the embankment.
- Increase the reflectivity of dark surfaces.
- Artificial cooling and/or extracting heat from embankment.
- For new roads, avoid permafrost areas altogether.

Sea Level Rise

- Map likely threatened areas.
- Installing warning signs.
- Upgrade coastal drainage systems/ add drainage canals in coastal roads.
- Edge-strengthening of road embankments.
- Elevation of roads, bridges and tunnels.
- Using submergible pavements.
- Additional pumping capacity for tunnels.
- For new roads:
  - numerical models to predict the extent of future flooding and potential erosion
  - new sea-defences

Flooding

- Draw up maps of flood prone areas, considering increasing precipitation and sea-level.
- Keep records of flooding events and locations.
- Clean out debris from clogged ditches and culverts.
- Clean out watercourses and structures in flood prone areas ahead of predicted heavy rainfall.
- Resize drainage systems to meet threat.
- Protect bridge piers and abutments with riprap.
- Addition of slope retention structure and retaining facilities for landslides.
- Pave ditches to reduce erosion.
- Increase the standard for drainage capacity for new infrastructure and rehabilitation projects.
- Prepare contingency/emergency plans.
- Protect evacuation routes.

Roads and Bridges Erosion

- Gravel roads:
  - stabilization
  - improved compaction and drainage
- Paved roads:
  - improved drainage
- Side slopes:
  - installing interception drains
  - terracing
- Vegetation
  - providing a retaining wall at toe
- Provision of armour protection to embankments on exposed coasts
- Bridges and structures
  - Inspecting before and after flooding events
  - Providing scour protection around piers and abutments
  - Providing armour protection against wave action where necessary

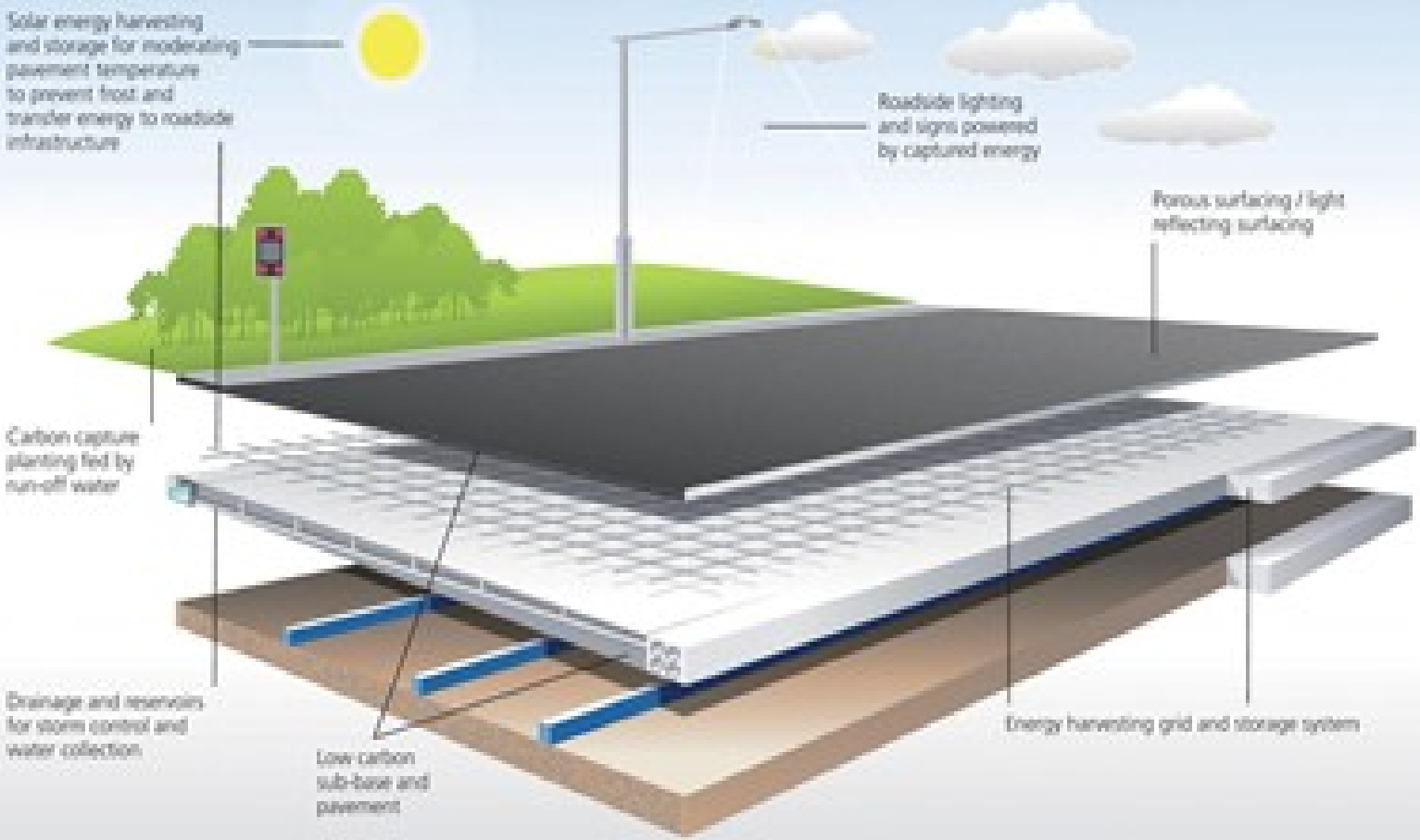
Slope failures, Landslides and Avalanches

- Cutting back slope to shallower angle.
- Terracing or benching the slope.
- Vegetating slope to provide organic reinforcement of the surface layers.
- Support slope with retaining structure.
- Implement a system of geotechnical risk management
- Mapping landslide and avalanche prone areas, including underlying geology.
- Structural and non-structural mitigation, e.g. catch fences.
- For new roads: avoid landslide risk areas.

Possible Low-Medium Cost Measures

- Temperature:
  - Increased cutting of verges and other vegetation, but taking into consideration biodiversity impacts.
- Precipitation:
  - Identify location of drains and their condition
  - Improved maintenance of drains and culverts
  - Strengthen embankments
  - Prepare a surface water management plan
- High winds and storms:
  - Risk assessment and replacement of trees and lightweight structures.

The climate change resilient road



Source: http://www.worldhighways.com

Conclusions and Recommendations

- Climate changes, if not mitigated, could have a significant effect on road networks.
- **EU: White Paper on adapting to climate change:** More strategic and long term approach to spatial planning will be necessary in road transport.
- Adaptation measures should be cost-effective and sustainable.
  - Adapt and change design standards to cope with new climate conditions.
  - Develop framework to preset an acceptable level of service during the occurrence of extreme weather conditions.
  - Develop framework for the system recovery to normal operating conditions.
- Climate change should be included into daily engineering management, and integrated into policies and regulations.
- Raise awareness and share knowledge on good practices.

Thank you for your attention!