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Effects of Climate Change on Road Network Resilience

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Director Centre for Pavement and Transportation Technology

Seminar Challenges for resilient road networks
Santiago Chile
October 18, 2016

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Presentation Overview

- Introduction
- Climate Change
- Natural Disasters
- Road build-in resilience strategies
- Closing Remarks

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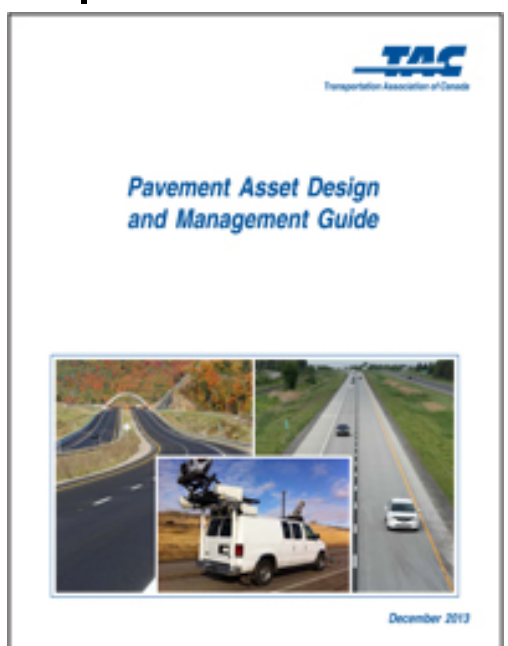
Pavement Asset Design and Management Guide

- Leading the Development of the Transportation Association of Canada (TAC) design guide
- Resulted in many positive changes to Canadian standards and specifications



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Pavement Asset Design and Management Guide

- Includes a new chapter on Climate Change and Sustainability
- Focuses on provincial, municipal and city needs

[Reid and Hein 2016]

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Climate Change

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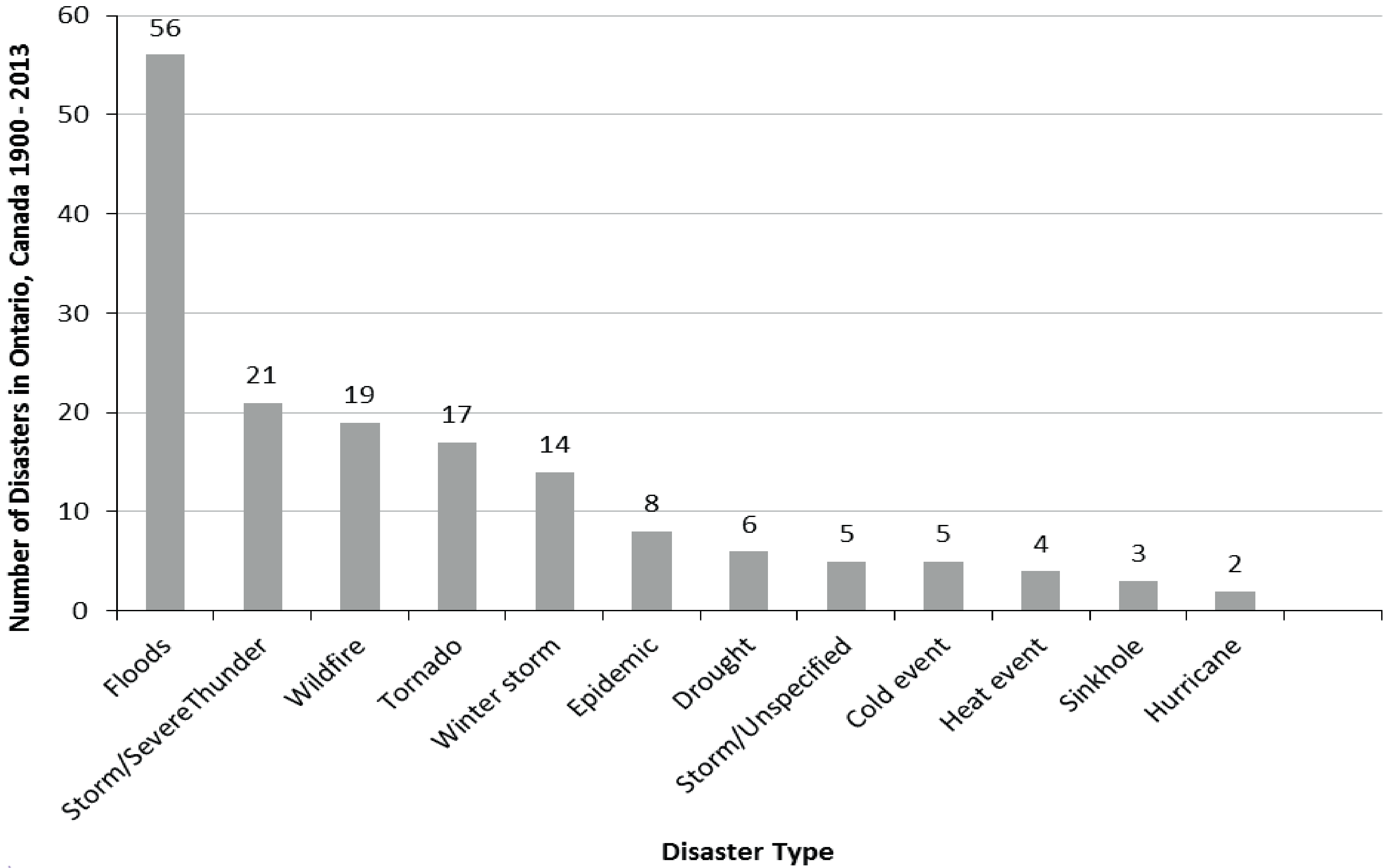
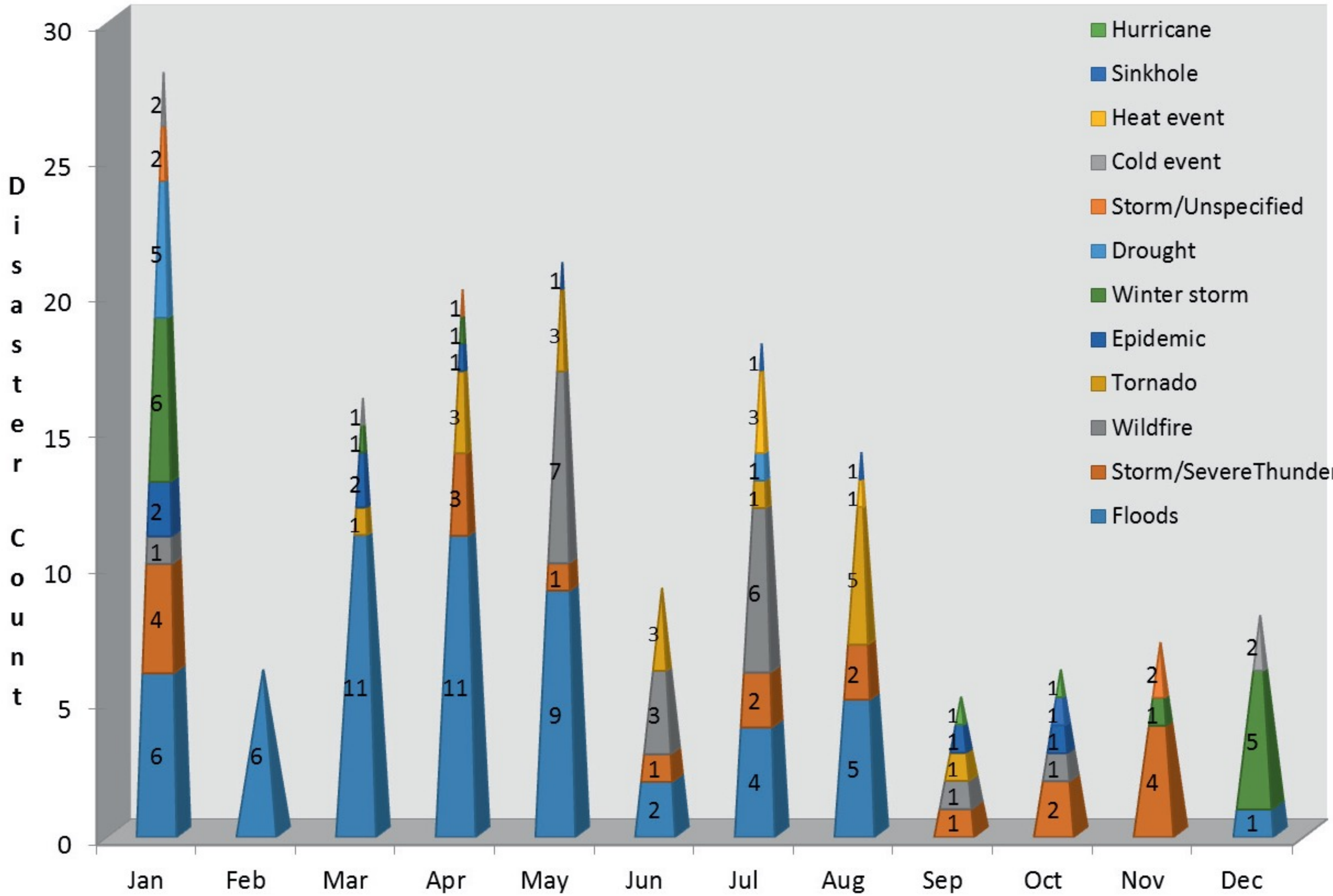
Disaster Types in Ontario 1900 – 2013



Nirupama, N., et al (2014). Natural Hazards in Ontario, Canada: An Analysis for Resilience Building. *Procedia Economics and Finance*, *18*, 55-61.

When does flooding occur?



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Assessment of Damage

Load type	Pavement damage reasons
Flood depth	Absorption of water
Flood duration	Absorption of water
Flood velocity	Force of water
Flood debris	Pavement surface texture reduction
Flood contaminants	Absorption or adhesion of contaminants carried by water

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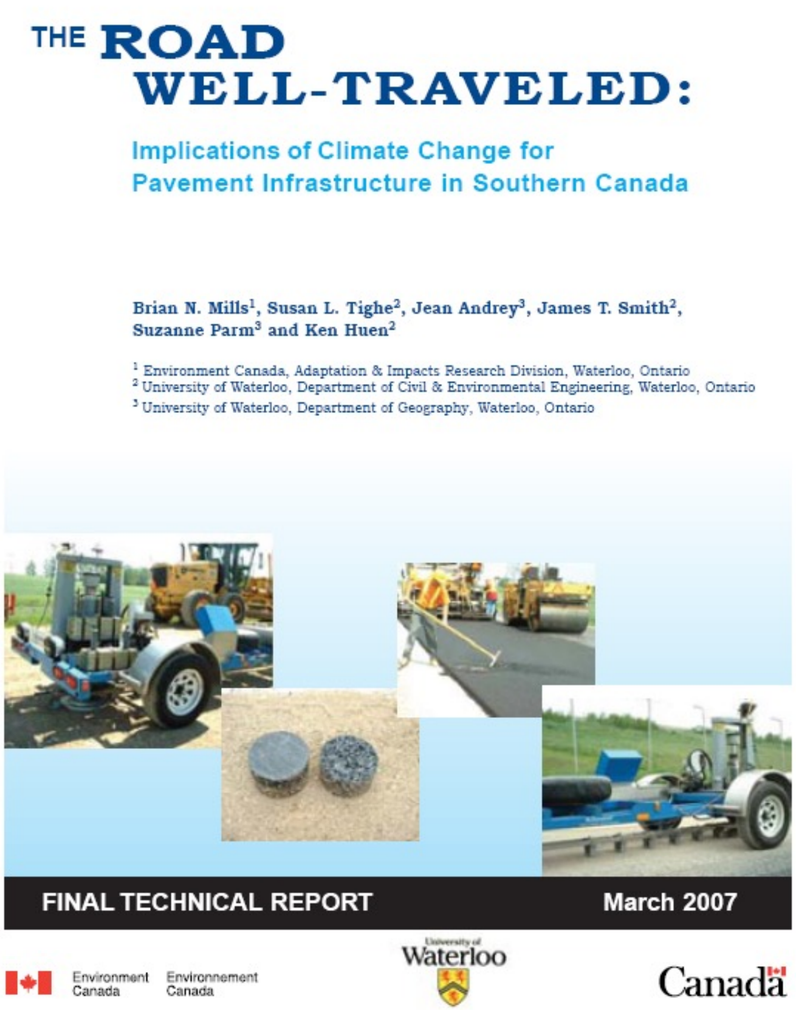
Climate Change Impacts



GLOBAL Climate Change

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Analysis of Performance Related Data

PROVINCE	British Columbia	Alberta	Manitoba	Ontario	Quebec	Newfoundland
LTPP Site Identification	82-1005	81-1804	83-6450	87-1806	89-1021	85-1808
Climatic Region	Wet-freeze	Dry-freeze	Wet-freeze	Wet-freeze	Wet-freeze	Wet-freeze
Climate station reference	1108447 Vancouver International Airport	3012205 Edmonton International Airport	5023222 Winnipeg International Airport	6158733 L.B. Pearson International Airport	7025250 P.E. Trudeau International Airport	
Latitude (degrees)	49.2	53.5	50.0	43.7	45.5	
Longitude (degrees)	-123.1	-113.5	-97.2	-79.6	-73.6	
Elevation (m)	4.3	723.3	238.7	173.4	35.7	
Traffic						
2-way AADTT**	1240	1420	498	2744	1912	
Percentage of truck traffic in design lane	100	100	100	100	100	
Pavement Structure						
Layer 1: Asphalt (cm)	9.7	8.4	5.1	4.1	5.3	
Layer 2: Asphalt (cm)	-	-	5.6	10.2	-	
Layer 3: Base (cm)	23.9	32.8	11.4	18.0	7.9	
Layer 4: Subbase (cm)	31.0	24.6	10.7	79.2	38.1	
Pavement Material						
Base	Crushed gravel	Crushed gravel	Crushed gravel	Crushed gravel	Crushed gravel	
Subbase	River-run gravel	River-run gravel	River-run gravel	A-4	Crushed gravel	
Subgrade**	SM	SM	SM	ML	SP	GW

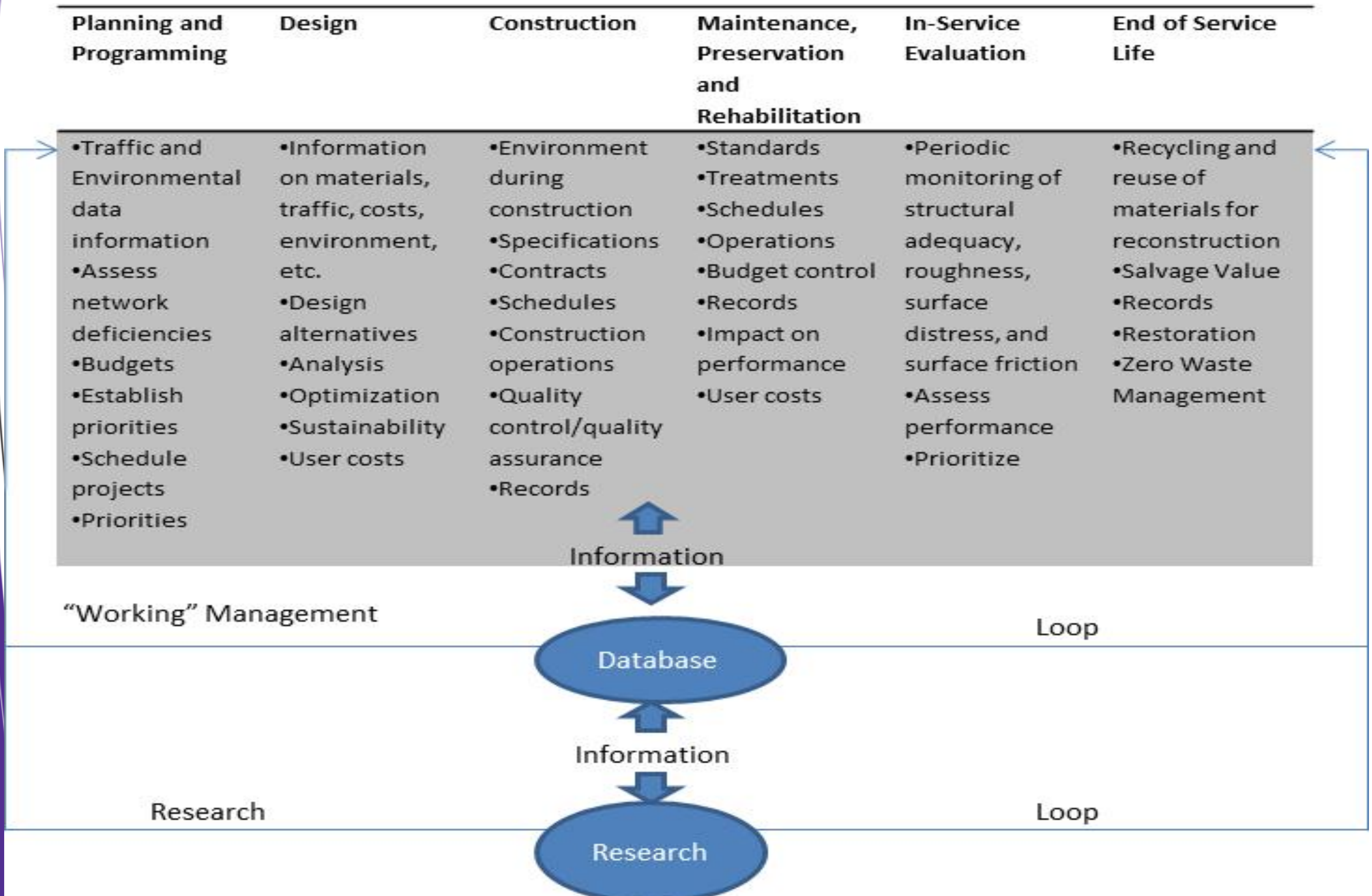
* Average Annual Daily Truck Traffic
** SM-silty sand or silty gravelly sand, GW-gravel or sandy gravel, well-graded; ML-silts, sandy silts, or diatomaceous soils; SP-sand or gravelly sand, poorly graded

1. **Influence of climate and climate change alone**
2. **Influence of structure type and baseline traffic volume**
3. **Combined influence of traffic growth and climate change**

(Mills, 2007)

Analysis of Performance Related Data

- Extreme minimum daily temperature (thermal cracking indicator)
- Seven-day average maximum daily temperature (rutting indicator)
- Freezing and thawing indices (indicator of frost and thaw depths)


Planning and Programming
Design
Construction
Maintenance, Preservation and Rehabilitation
In-Service Evaluation
End of Service Life
•Traffic and Environmental data information •Assess network deficiencies •Budgets •Establish priorities •Schedule projects •Priorities
•Information on materials, traffic, costs, environment, etc. •Design alternatives •Analysis •Optimization •Sustainability •User costs
•Environment during construction •Specifications •Contracts •Schedules •Construction operations •Quality control/quality assurance •Records
•Standards •Treatments •Schedules •Operations •Budget control •Records •Impact on performance •User costs
•Periodic monitoring of structural adequacy, roughness, surface distress, and surface friction •Assess performance •Prioritize
•Recycling and reuse of materials for reconstruction •Salvage Value •Records •Restoration •Zero Waste Management
Information
"Working" Management
Loop
Database
Information
Research
Loop
Research

(TAC, 2013)

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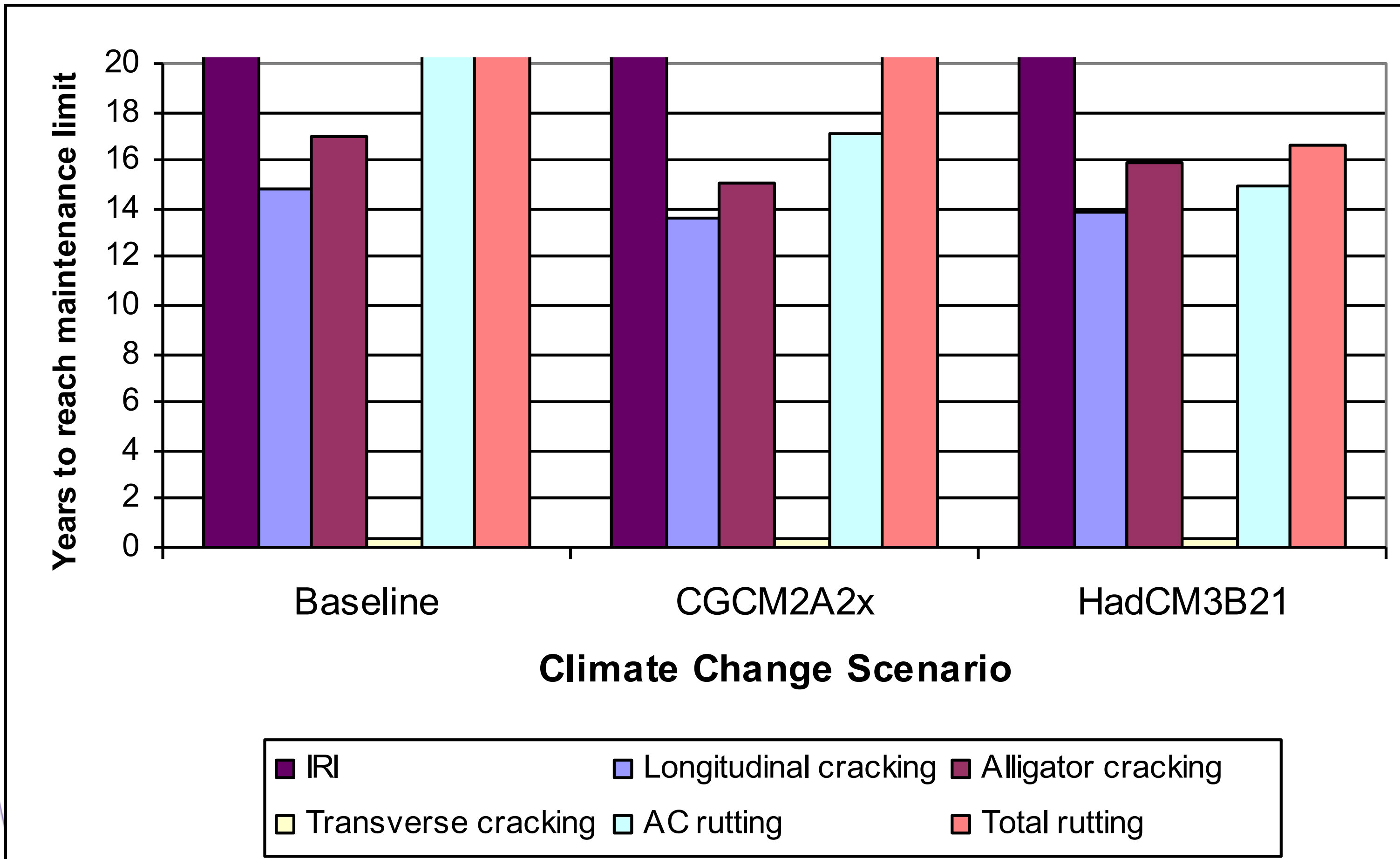
Alberta (Edmonton) site (50% reliability)



(Mills, 2007)

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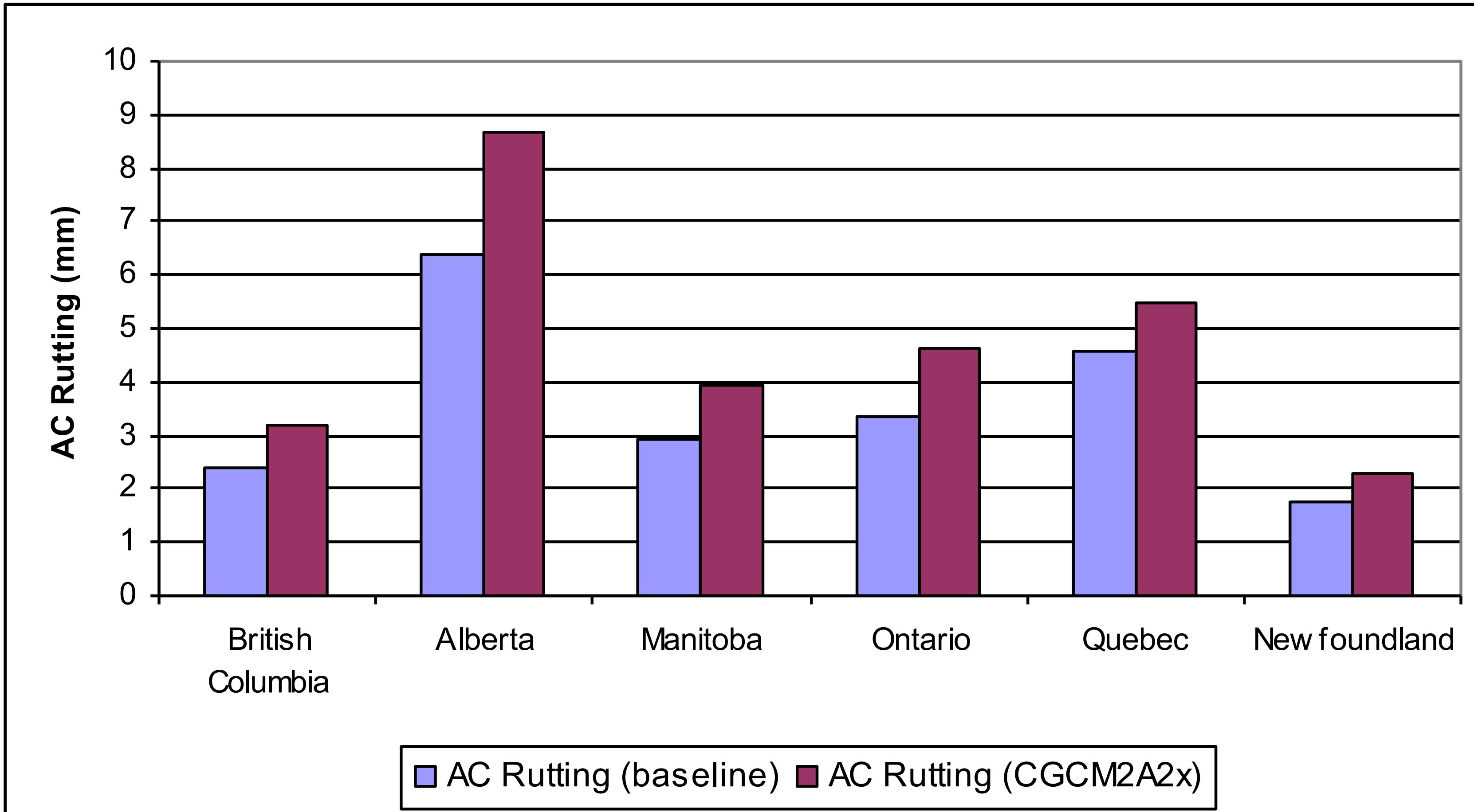
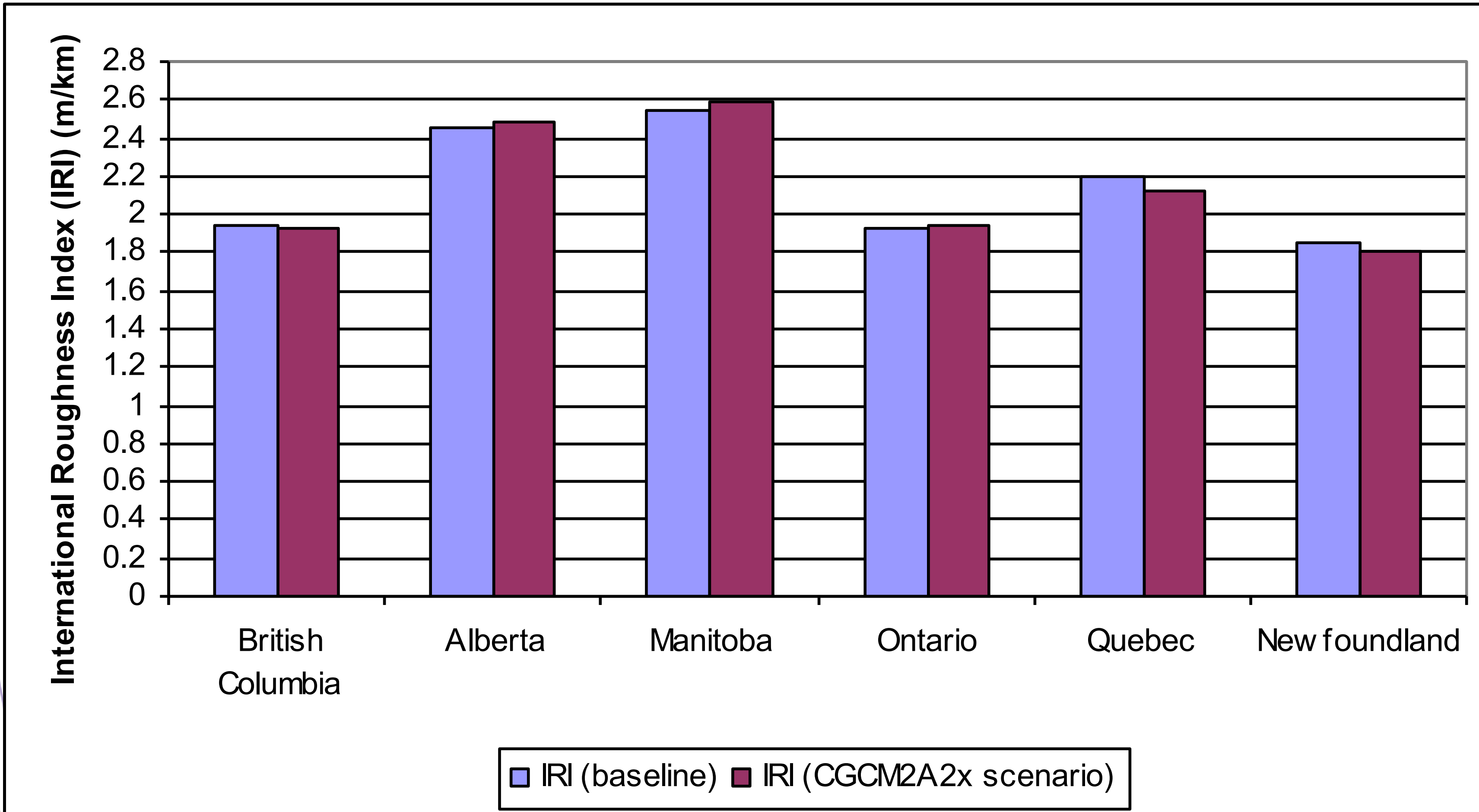
Pavement Predictions



(Mills, 2007)

Pavement Predictions



(Mills, 2007)

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Climate Change Impacts on Pavement

- Changes occurring in minimum daily temperature
- Changes occurring in maximum daily temperature
- Changes occurring in freezing and thawing indices
- Changes occurring in precipitation, duration and intensity
- All of these changes are impacting infrastructure
- Reconsider current design methods, maintenance and rehabilitation practices
- Manage implications

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What is a Natural Disaster?

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Role of Engineers and Scientists

- Many of these could possibly be avoided by better design, construction, safety systems, early warning and planning.
- Scientists and engineers try to prevent damage by warning people the natural disaster is coming.
- Try to monitor the event and try to prevent damage.
- Develop plans for emergencies

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Key Sustainability Issues

- Virgin Material Usage
- Alternative Material Usage
- Program for In-Service Monitoring and Management
- Air Quality/Emissions
- Water Quality
- Noise
- Energy Usage



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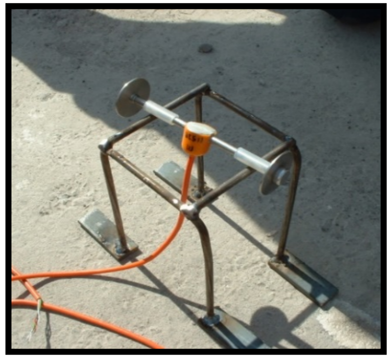
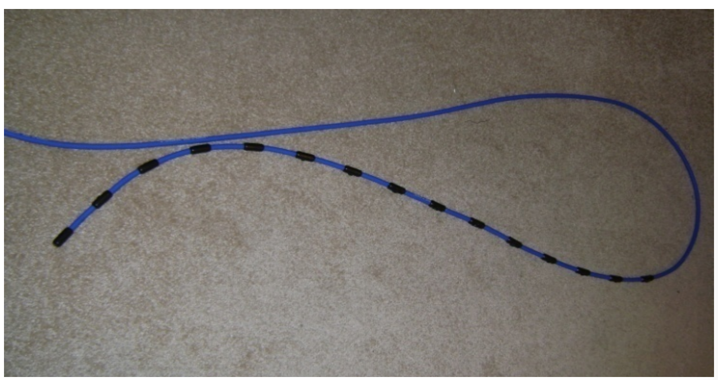
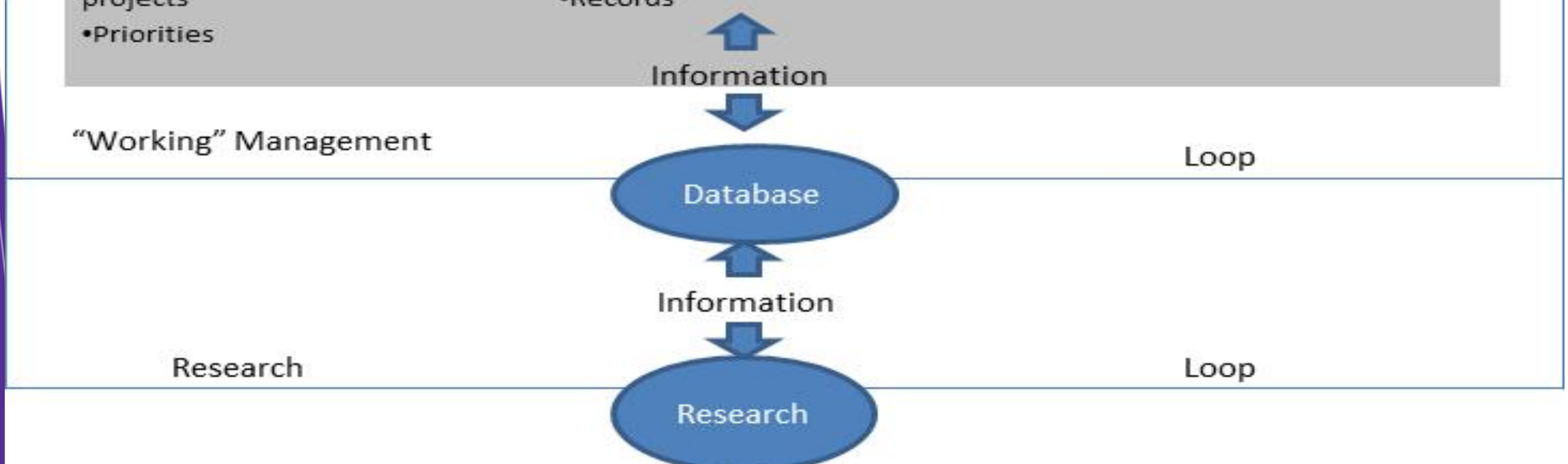
Research Methodology

- Technical
- Economic
- Sustainable
- Costs/Benefits



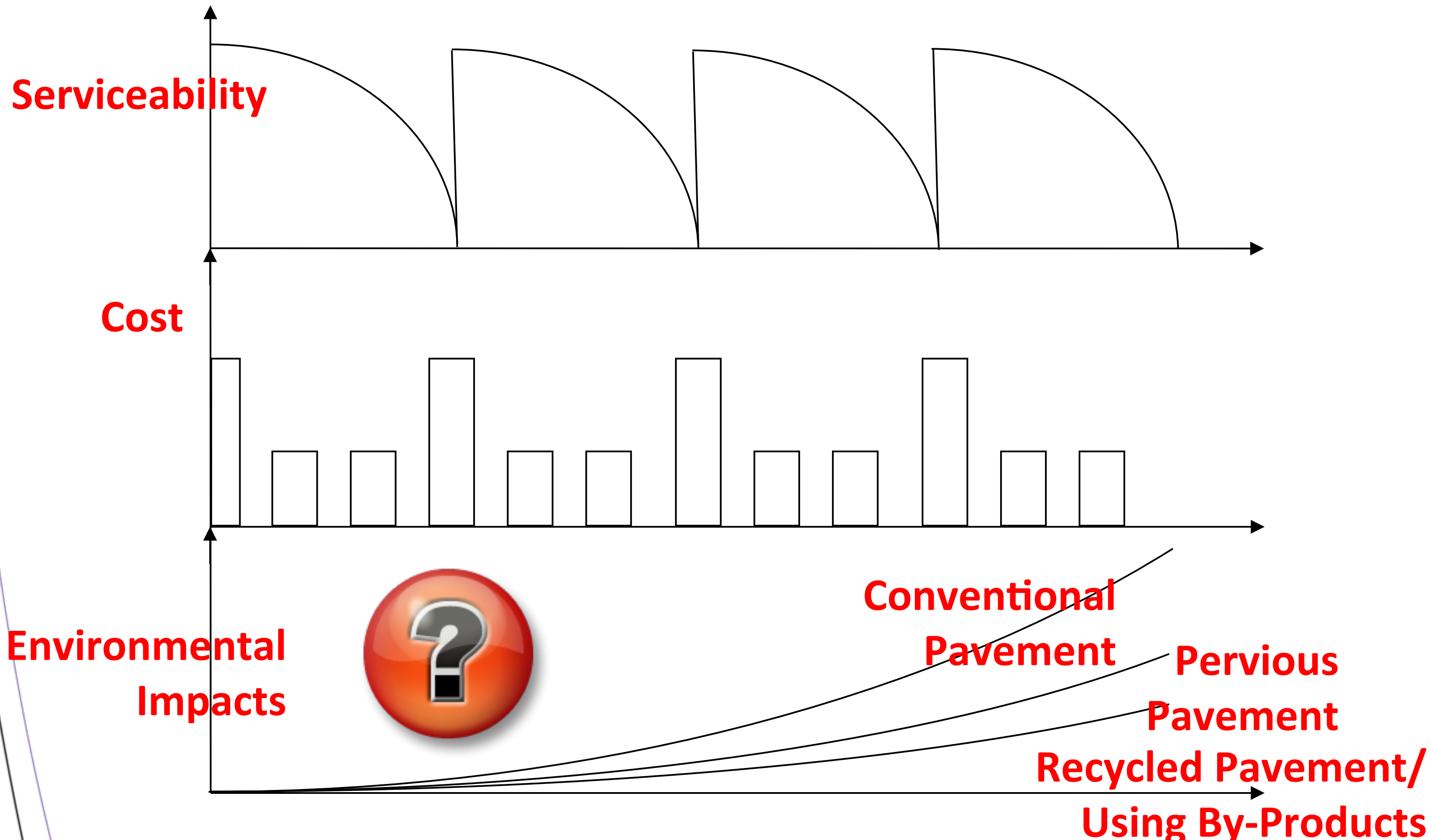


Planning and Programming	Design	Construction	Maintenance, Preservation and Rehabilitation	In-Service Evaluation	End of Service Life
•Traffic and Environmental data information •Assess network deficiencies •Budgets •Establish priorities •Schedule projects •Priorities	•Information on materials, traffic, costs, environment, etc. •Design alternatives •Analysis •Optimization •Sustainability •User costs	•Environment during construction •Specifications •Contracts •Schedules •Construction operations •Quality control/quality assurance •Records	•Standards •Treatments •Schedules •Operations •Budget control •Records •Impact on performance •User costs	•Periodic monitoring of structural adequacy, roughness, surface distress, and surface friction •Assess performance •Prioritize	•Recycling and reuse of materials for reconstruction •Salvage Value •Records •Restoration •Zero Waste Management



(TAC, 2013)

Quantify All Costs/Benefits



(Tighe, 2010)

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Long Life Design

- Resilience is the ability to deal with changes in general
- Resilience in pavement engineering design to ensure it withstands hazard with minimum damage of pavement
- Build-in pavement resilience from material revolution view
- Pavement resilience from post disaster using pavement management to better manage future road

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Closing Remarks

- Understand climate Change must be examined for Long Life Infrastructure
- Adoption of new materials and designs
- Evaluate potential threats related to climate change and plan for them
- Proactive design and management

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ohmpa
Ontario Hot Mix
Producers Association

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Questions/Comments

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