Design and Rehabilitation Strategies for Sustainable Concrete Pavements

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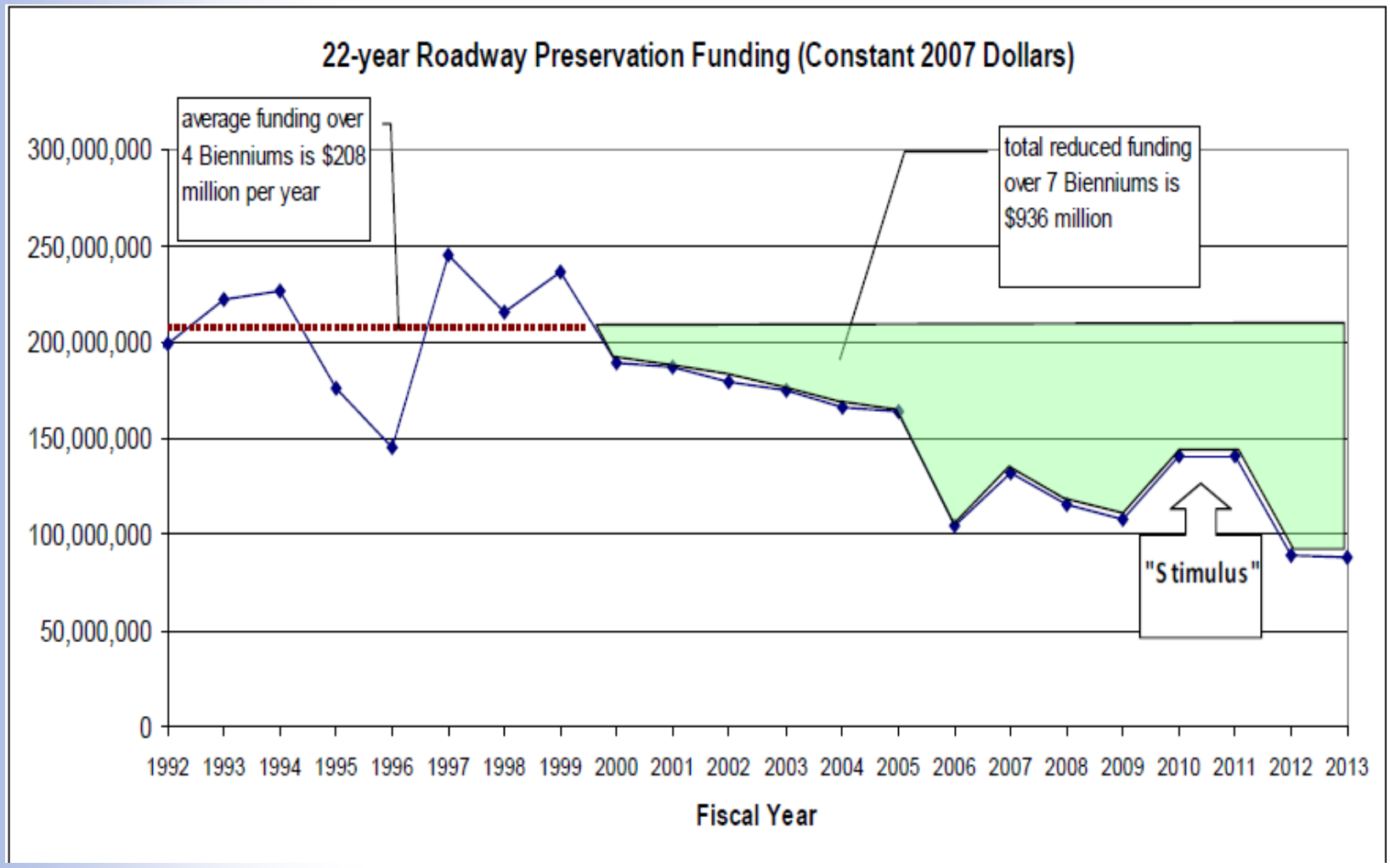
SUSTAINABILITY

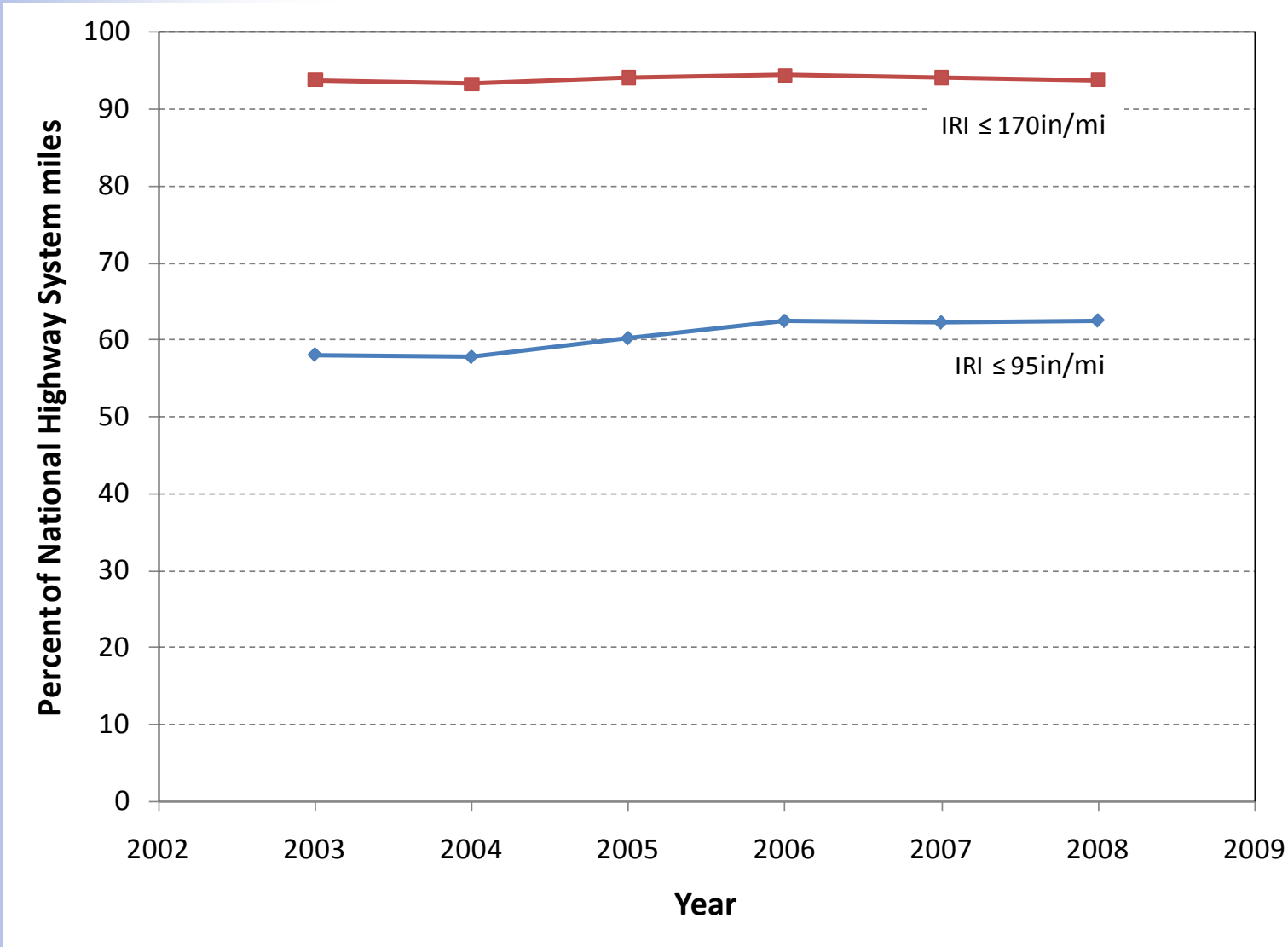
Sustainability

- To a highway agency, sustainability, first and foremost, is the ability to provide pavements in its charge in an acceptable condition
- Indication of unsustainable practice
  - Mounting backlog of pavement rehab needs
  - Annual shortfall of roadway budget for meeting critical needs is estimated at $116 billion

Washington State's roadway preservation budget trend (Mahoney et. al 2010)



Smoothness trend of NHS (HPMS)



Key points

- Economic sustainability is the biggest challenge facing DOTs today
- The long-life pavement approach greatly enhances the highway agencies' ability to meet the pavement needs
  - Building long-life, low-maintenance pavements
  - Taking proactive measures to preserve the pavement
- The sustainability is improved automatically

50-year-old PCC pavement

Via Apia, 312 B.C.

Current practice

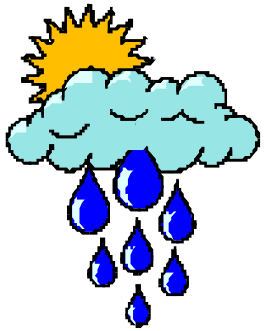
- Pavements are designed to fail
  - Finite design period
  - Pavements are designed for relatively high levels of distress at the end of the design period
- Repairs are not made until distresses progress to high severity
- Structural overlays are used primarily as a corrective measure
  - Typically used on pavements in poor condition
  - A thicker overlay is generally required

What is needed

- Design pavements to last as long as the materials
  - Pavements should remain distress-free within the design period
  - Utilize design features that ensure good long-term performance
- Apply preventive treatments to preserve the pavement structure
  - For sustainability, preservation is better than reconstruction
  - Prevention is the best preservation strategy

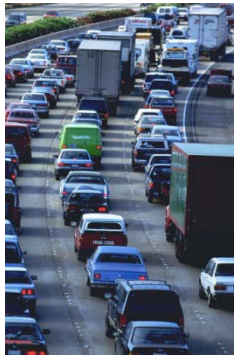
ME design

Trial Design



Climatic Data

Material Properties



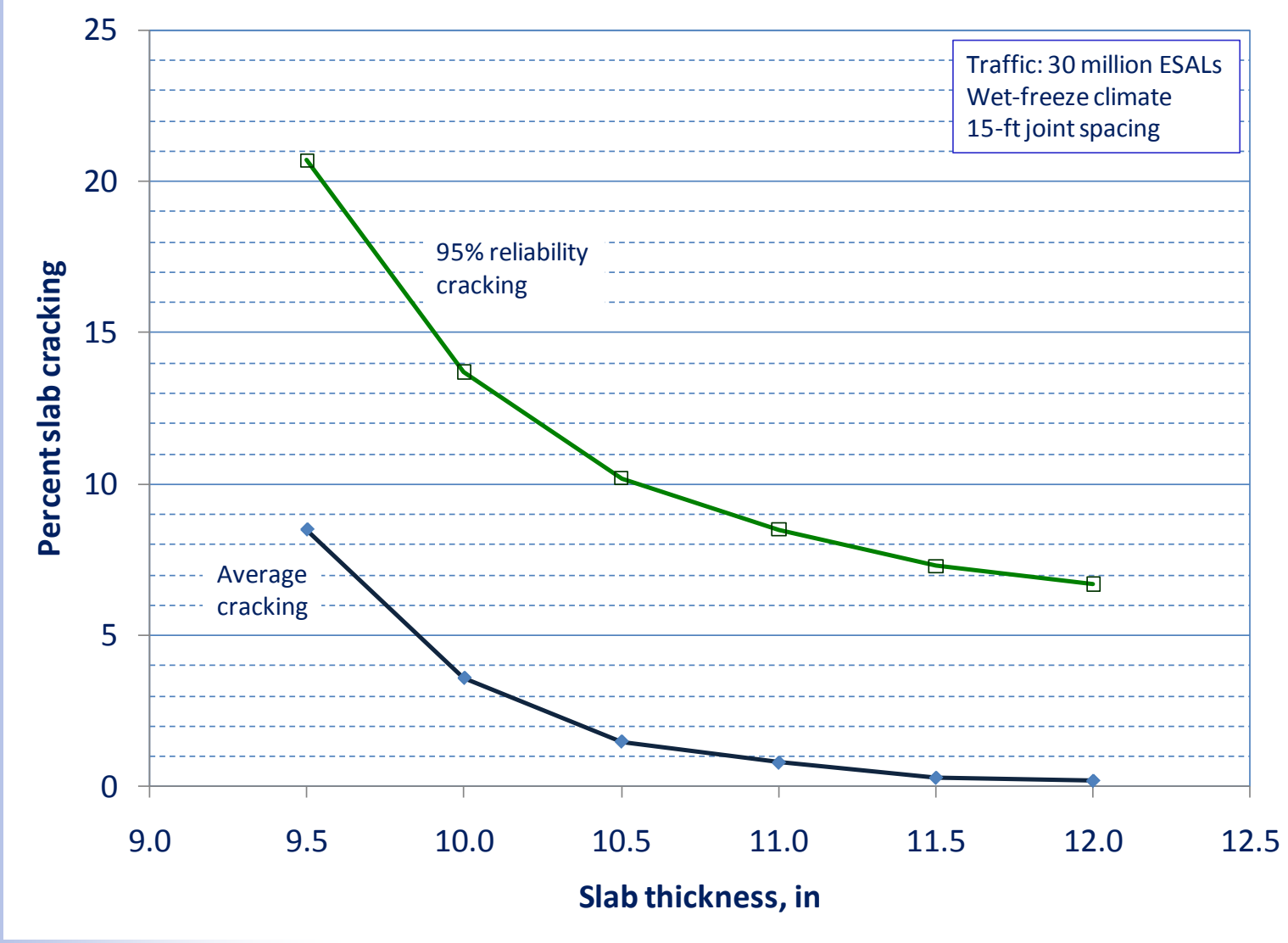
Traffic

Predicted Performance

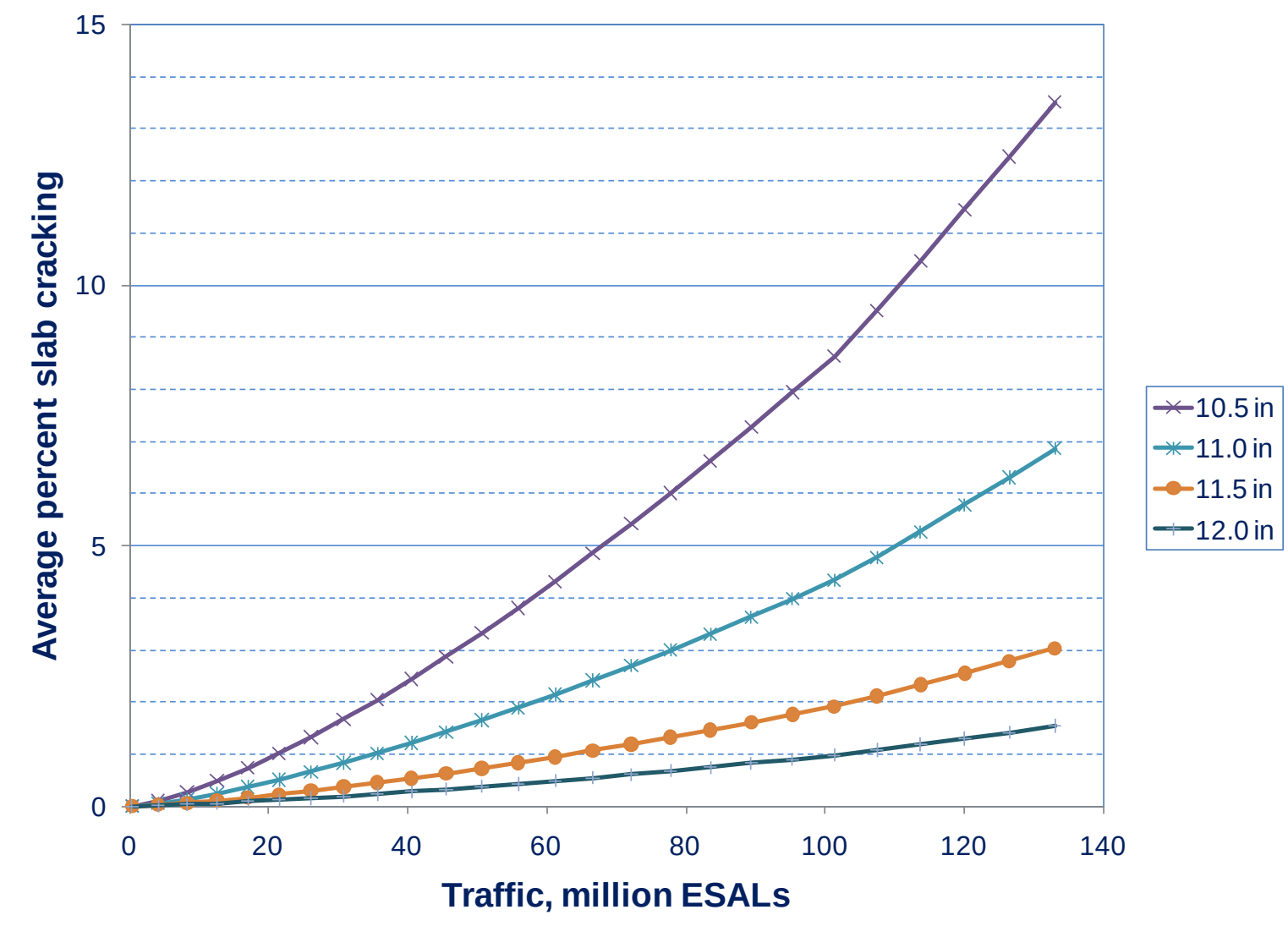
Design Guide Software

Mechanistic Analysis

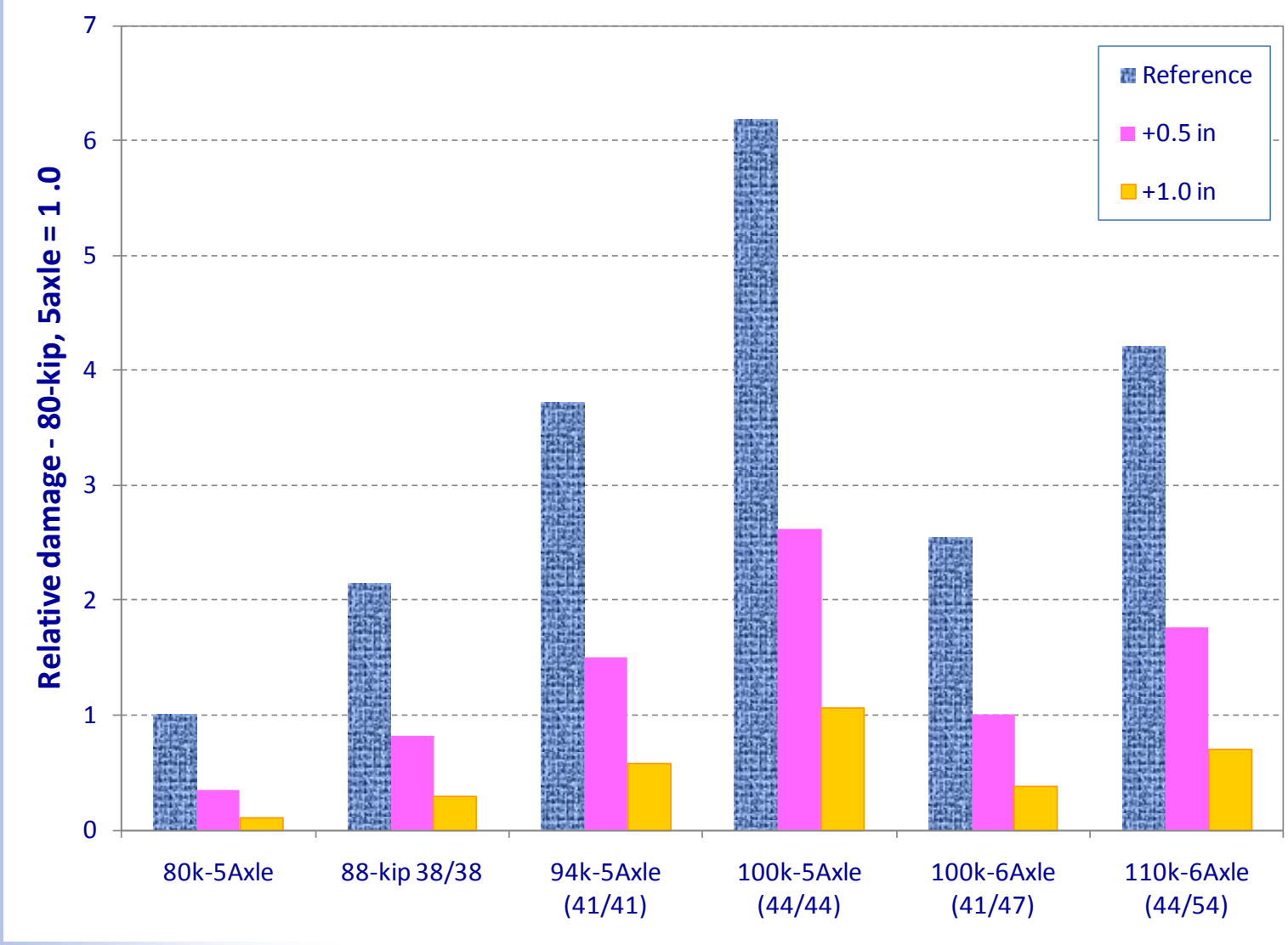
Effects of slab thickness on cracking (MEPDG)



Effects of slab thickness on traffic capacity (MEPDG)



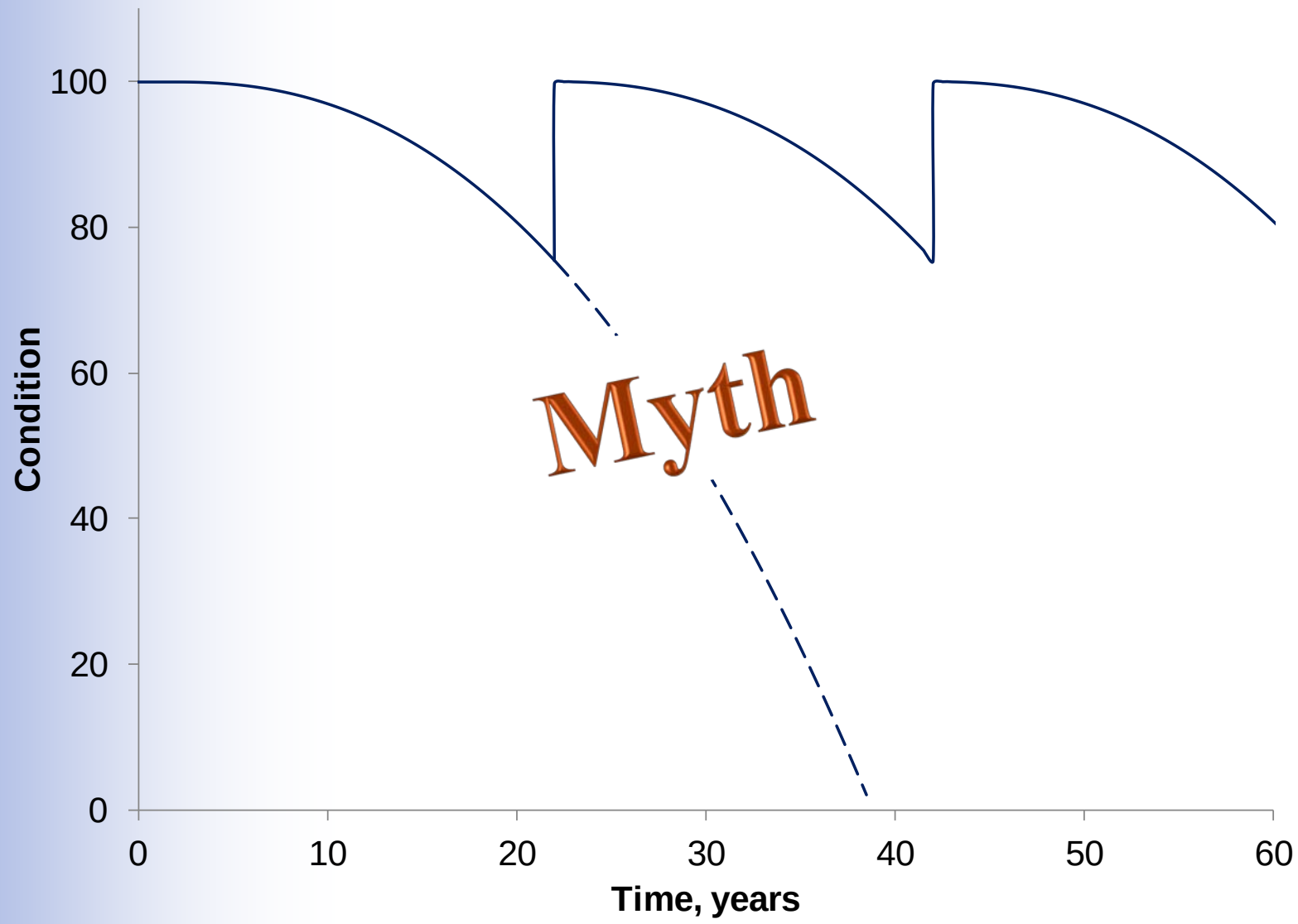
Benefits of conservative design (MEPDG)



Sustainable rehabilitation strategy

- Repair cracks while they can be effectively treated by dowel or tie bar retrofit
  - Less intrusive, and is at least as effective as full-depth repair (similar service life)
  - Significantly lower cost
- Apply structural enhancements when structural cracks begin to develop
  - A relatively thin HMA overlay can be highly effective in greatly extending service life

Pavement condition vs. age



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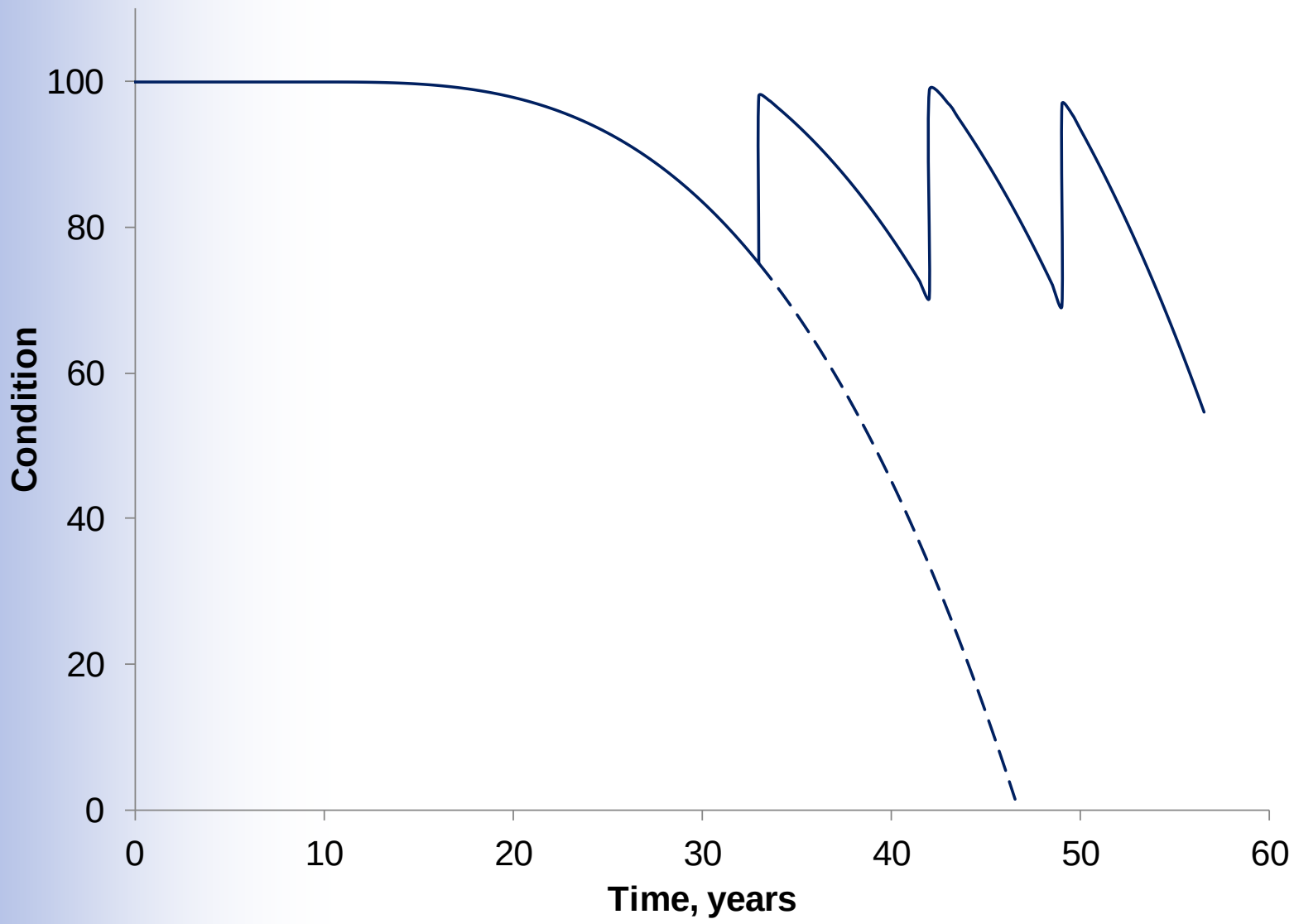
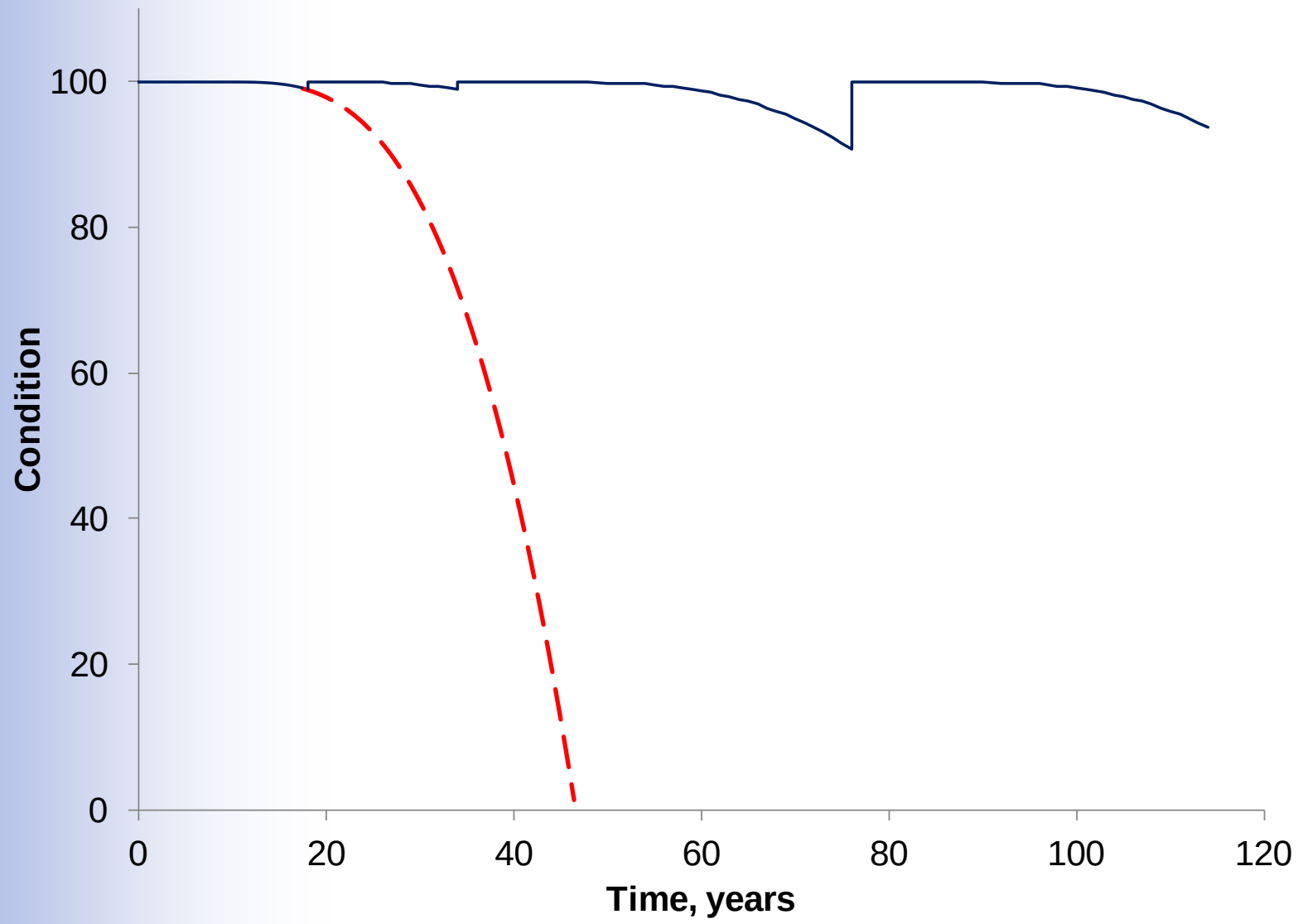
Pavement condition vs. age – current practice



Pavement condition vs. age – preservation approach



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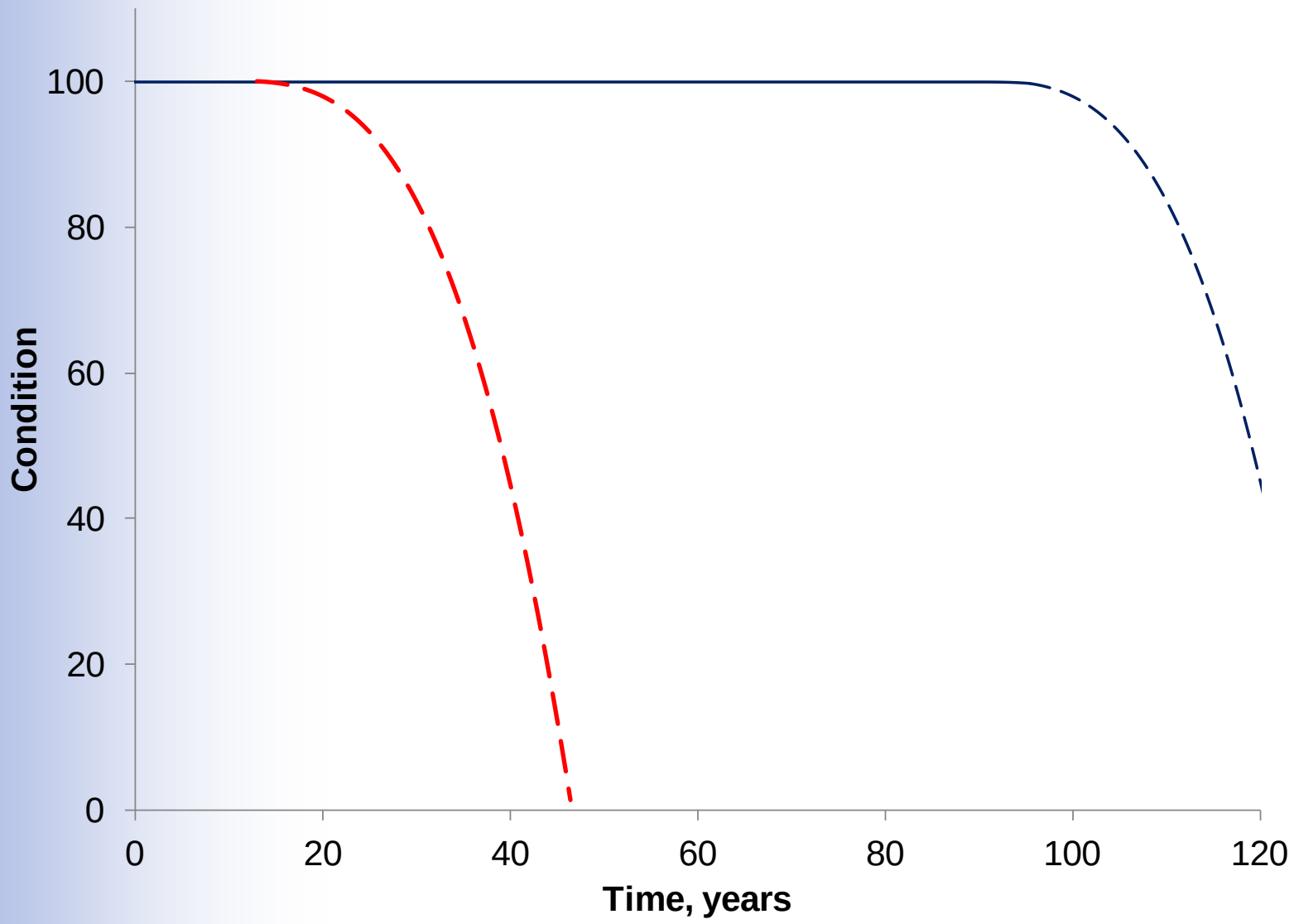
Pavement condition vs. age – long-life pavement



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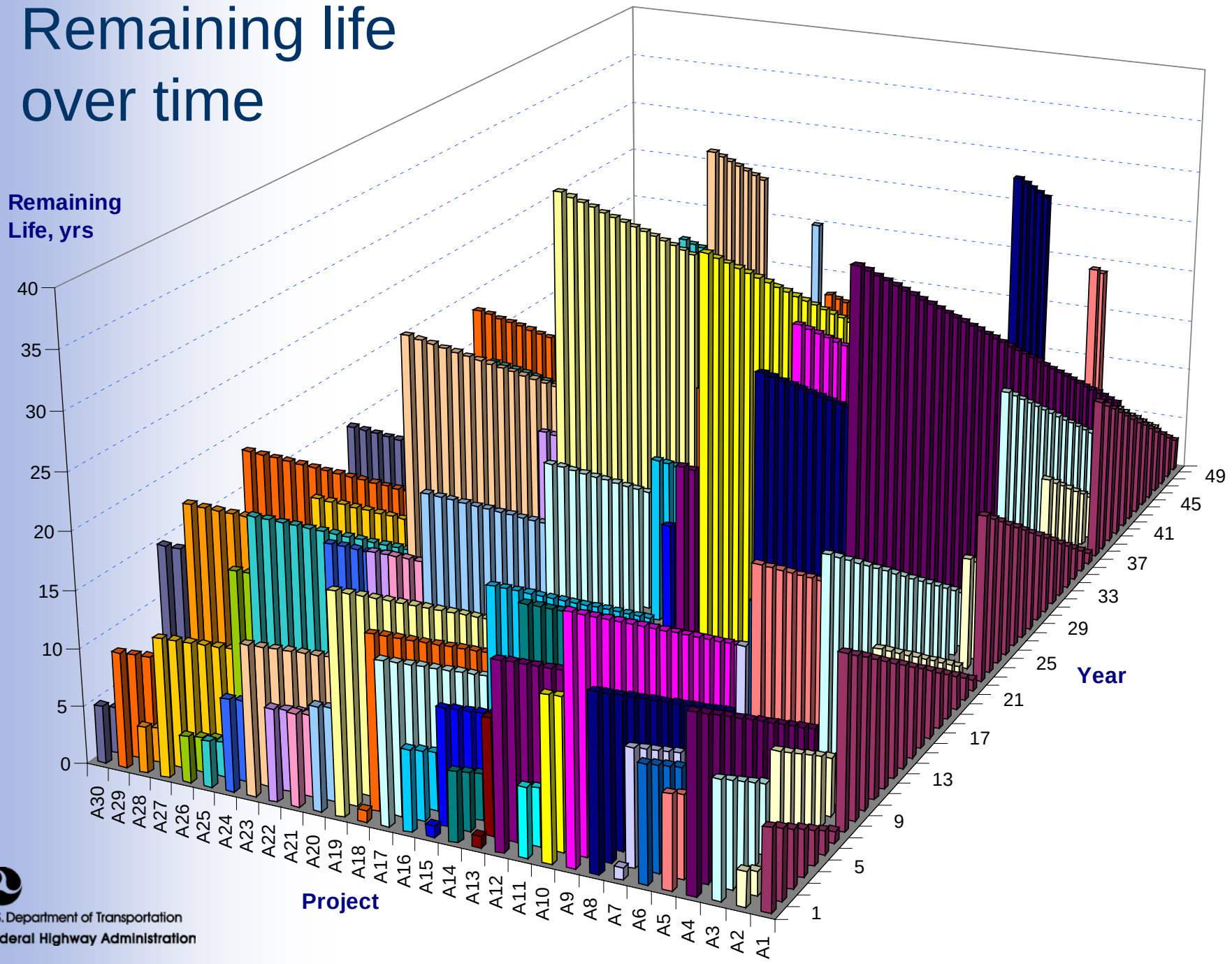
Cost Considerations

Current practice

Cost considerations

- Minimizing LCC of a single project does not provide the best results for the network
- Highway investment decision is a resource allocation problem
- At any given funding level, the optimum solution is one that buys the most service life for the network: total lane-mile-years

Remaining life over time



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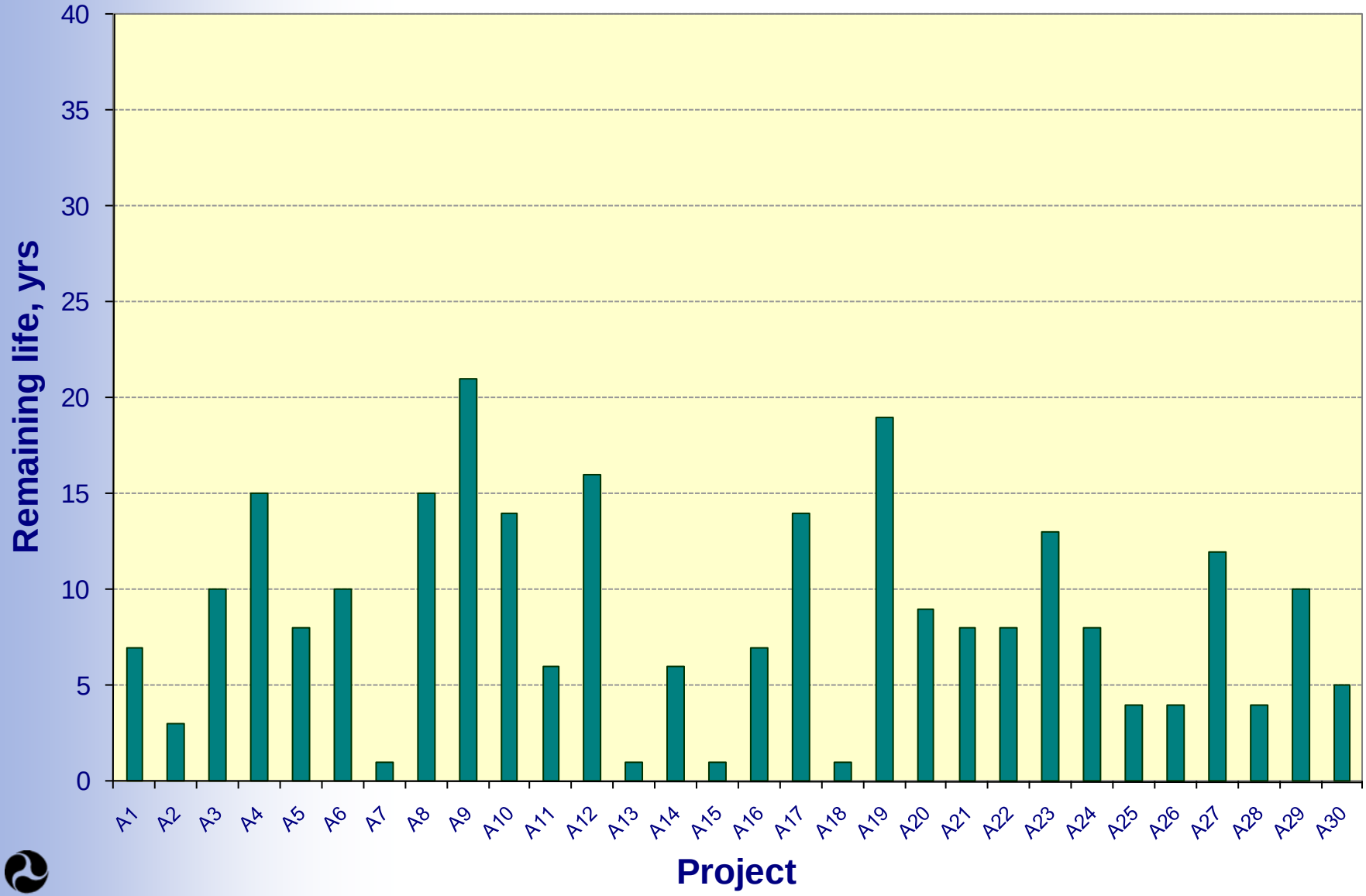
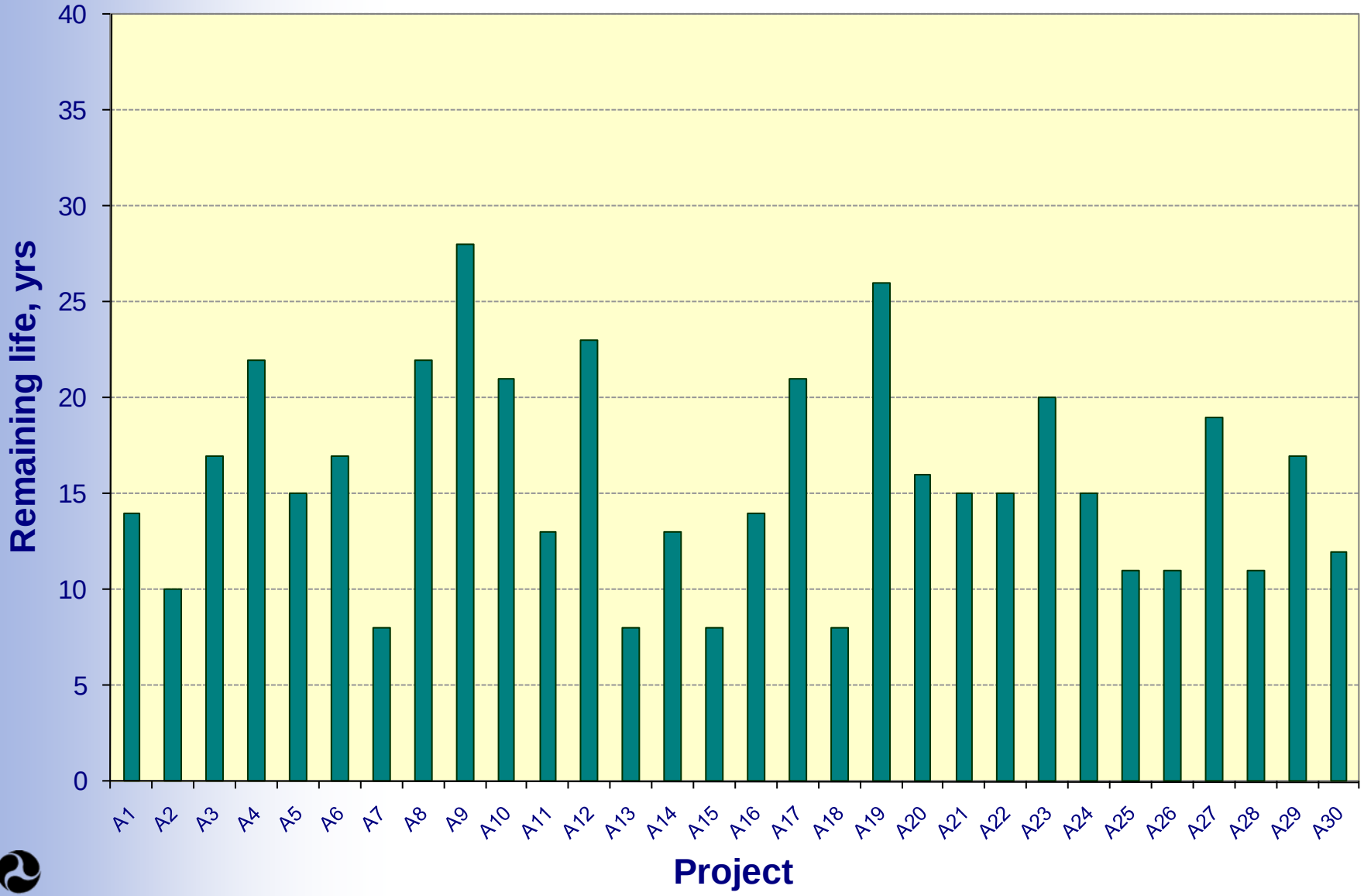
Remaining life of project in the network, year 0



Remaining life of project in the network, year x



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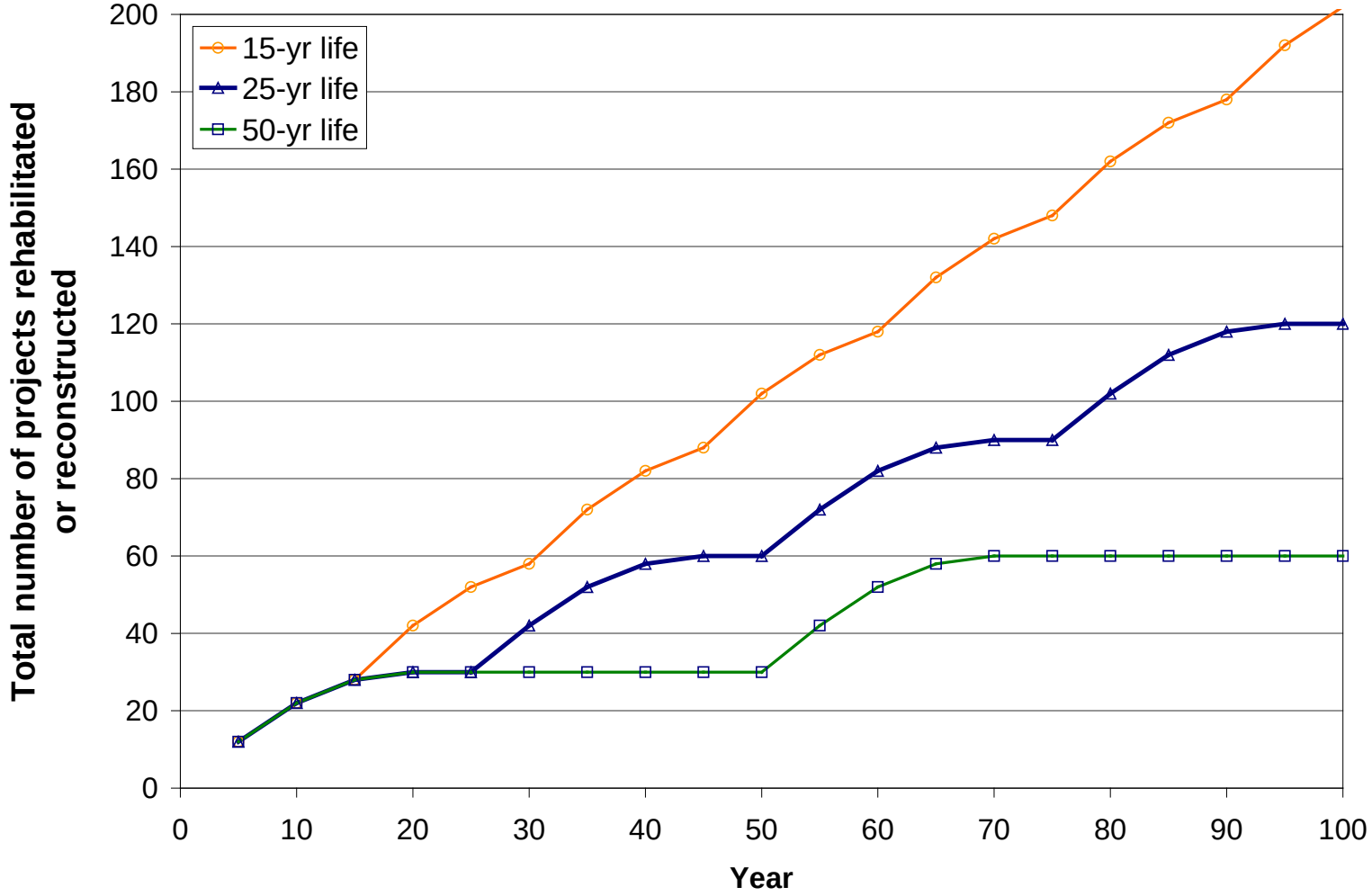
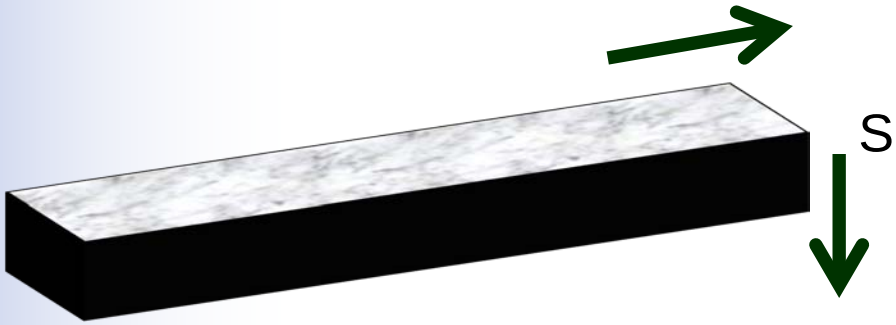
Effects of service-life on project load



Two Dimensions of Paving

Coverage: lane-miles



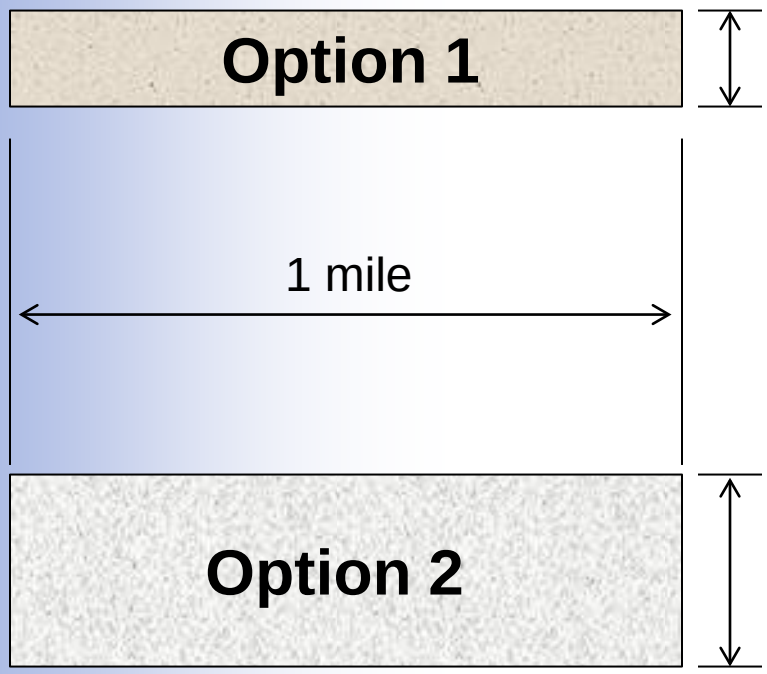
Service Life: years

Unit of Paving = **lane-mile-years**

A network of x lane-miles of pavement requires an addition of x **lane-mile-years** of service life each year to maintain status quo

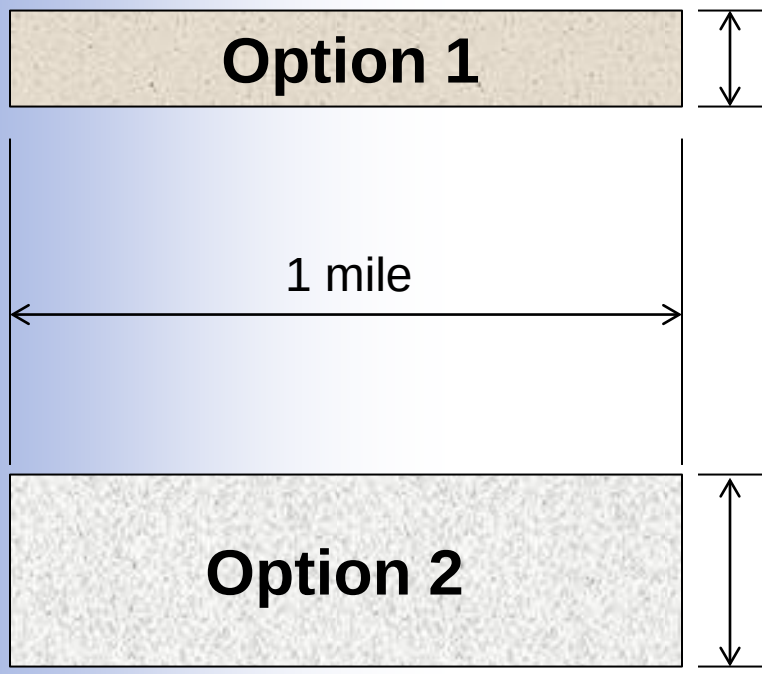
A Quick Check of Your Highway Network Health: FHWA-IF-07-006

Measure of Paving Costs



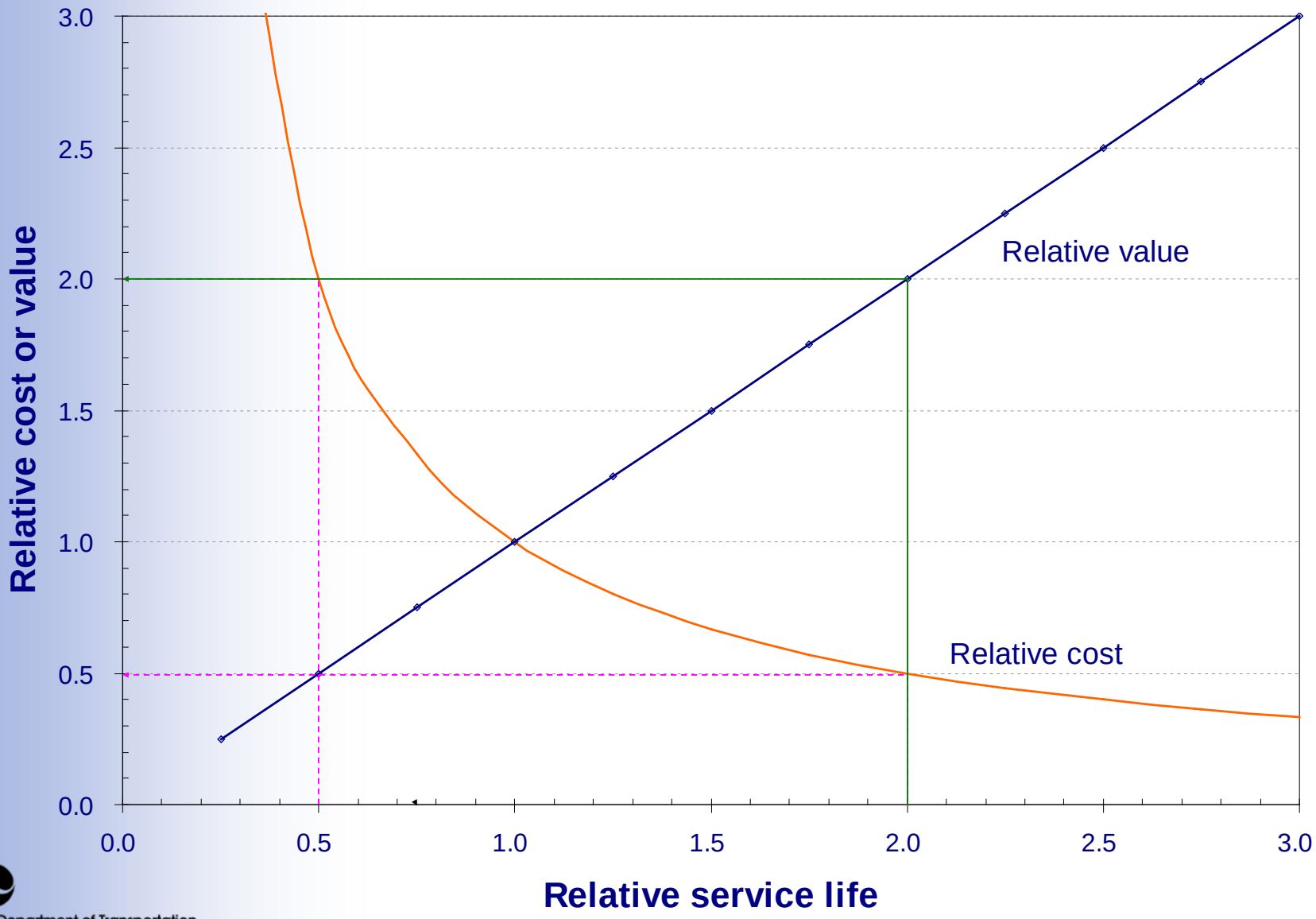
	Life	Cost	Unit Cost
Option 1	15 yrs	$200	$13.33 / lane-mi-yr
Option 2	30 yrs	$220	$7.33 / lane-mi-yr

Measure of Paving Costs



	Life	Cost	Unit Cost
Option 1	15 yrs	$200	$13.33 / lane-mi-yr
	13 yrs	$45	$3.46 / lane-mi-yr
	12 yrs	$45	$3.75 / lane-mi-yr
	40 yrs	$290	$7.25 / lane-mi-yr
Option 2	30 yrs	$220	$7.33 / lane-mi-yr
	10 yrs	$30	$3.00 / lane-mi-yr
	10 yrs	$30	$3.00 / lane-mi-yr
	50 yrs	$280	$5.60 / lane-mi-yr

Effects of service life on relative cost/value



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LCC vs $/lane-mi-yr for Roman Road

	Life	Agency Cost	PV	Unit Cost
	23 yrs	$150 /mi Reconstruct 99 times	$2.5 /mi	$65,220 / lane-mi-yr
	2,300 yrs	$3.0 /mi	$3.0 /mi	$1,300 / lane-mi-yr

Summary

- Current practices are not conducive to realizing the full performance potential of pavements
- Preferable practices
  - Design pavements to last as long as the material
  - Make repairs as early as possible to prevent further deterioration
  - Use overlays as a preventive treatment to preserve the pavement structure
- Evaluate cost as a resource allocation problem
  - Key parameter: **$/lane-mi-year**
  - Over time, optimizing $/lane-mi-year will minimize the number of projects that needs to be reconstructed