Polymer Modified Asphalt Performance and Life Cycle Costing
Understanding the True Economics

Ohio Asphalt Pavement Conference
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Today's Overview

- **Performance Study of PMA**
  - **Quantifying the Benefits**
- **LCCA Basics**
- **Impact of Using PMA on LCC**
  - **Example Scenarios**

Agency Design Engineer's Perspective

- PMA is One of Many Tools Available
- Performance Benefits Acknowledged
  - Lab and Field
- The Big Question:
  - How Do I Quantify the Benefits?

Quantifying the Effects of PMA for Reducing Pavement Distress

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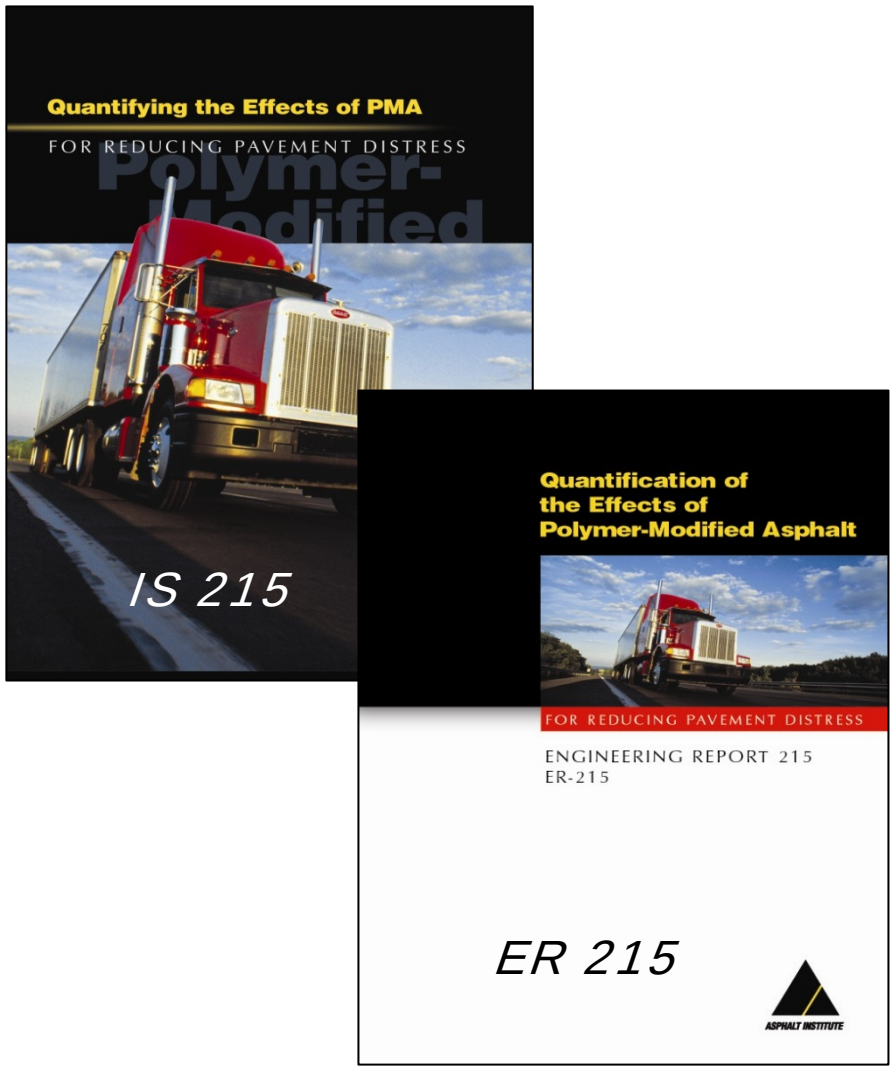


This study (published in Feb 2005) uses national field data to determine enhanced service life of pavements containing polymer modified binders versus conventional binders. The data is from a variety of climates and traffic volumes within North America.

Study Sponsors

Industry Associations

- The Asphalt Institute
- The Association of Modified Asphalt Producers

Federal Highway Administration

Corporate Sponsors

- Arr-Maz Products
- ATOFINA Petrochemicals, Inc.
- Dexco Polymers LP
- Dynasol LLC
- KRATON Polymers
- Polimeri Europas Americas
- Ultrapave

Study Team

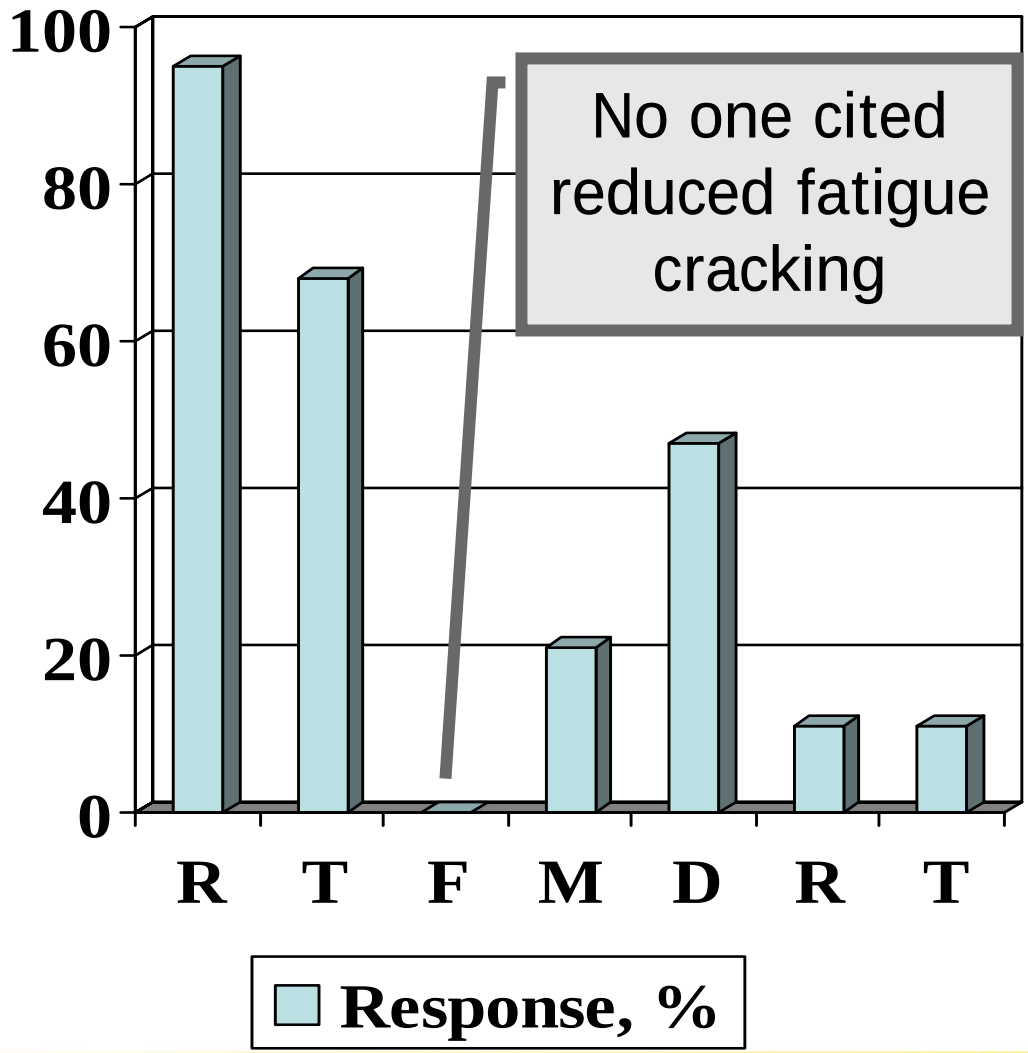
Project Team

- PI: Harold L. Von Quintus, P.E.
- And Associates

Study Objectives

1. Quantify the effect of using PMA as compared to conventional-unmodified HMA mixtures in terms of:
   - Increasing pavement life
   - Reducing occurrence of distresses
2. Identify conditions that maximize effect of PMA to increase HMA pavement & overlay life.

Agency Survey: Reasons for Using PMA?



R = Rutting

T = Thermal Cracking

F = Fatigue Cracking

M = Moisture Damage or Stripping

D = Durability

R = Raveling

T = Tenderness

Field Test Sections

- FHWA's LTPP
  - **SPS-1; SPS-5; SPS-6; SPS-9**
  - **GPS-1; GPS-2; GPS-6; GPS-7**
- M.T.Ontario Modifier Study
- Accelerated Pavement Tests
  - **FHWA ALF**
  - **NCAT Test Track**
  - **California HVS Studies**
  - **Ohio Test Road**
  - **Corp of Engineers**

Locations of Test Sections

- PMA and Unmodified Companion

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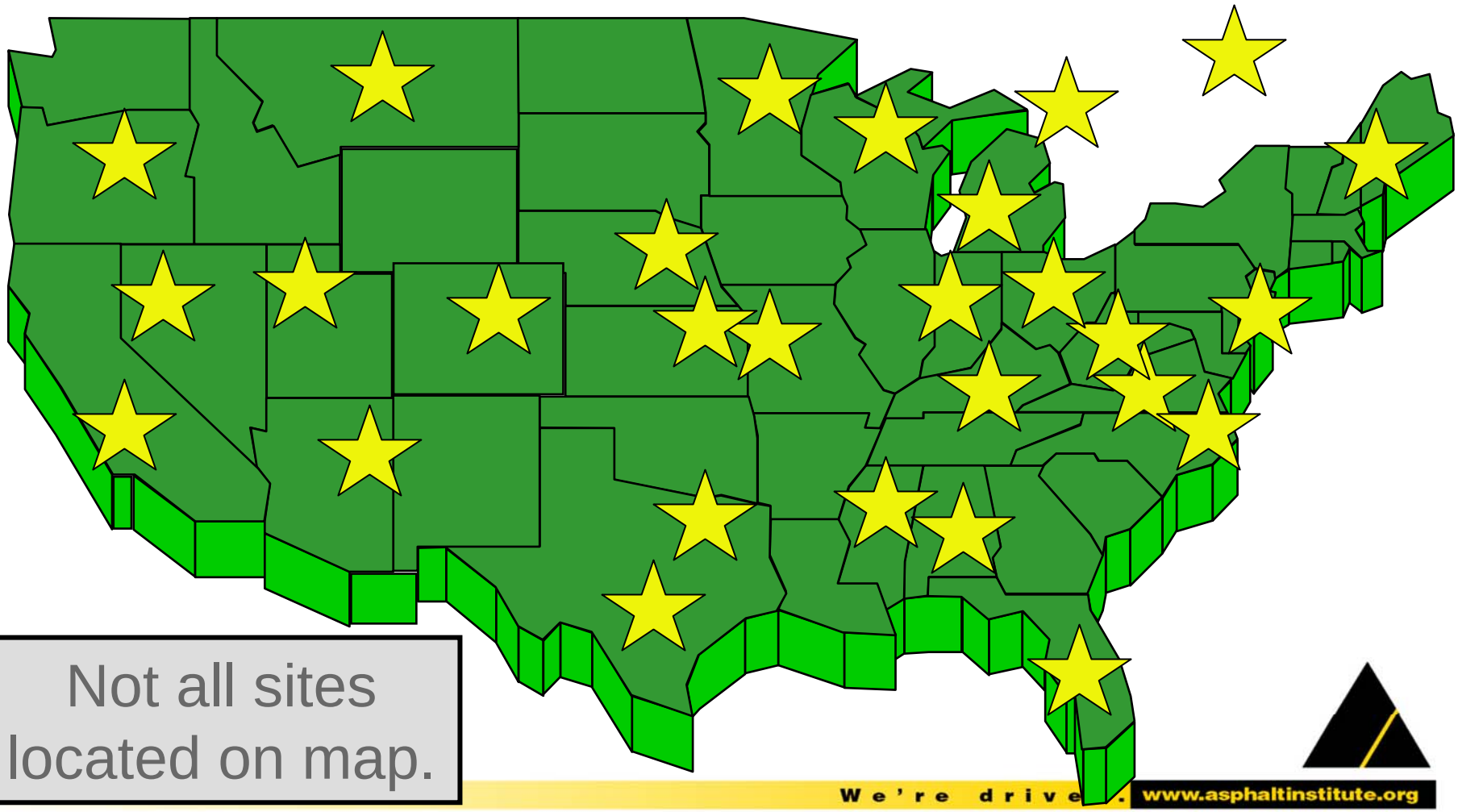

Not all sites located on map.

Pavement Surface Distress Data Collected/ Compared

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- Fatigue Cracking
- Rutting
- Thermal Cracking

Experimental Factorial

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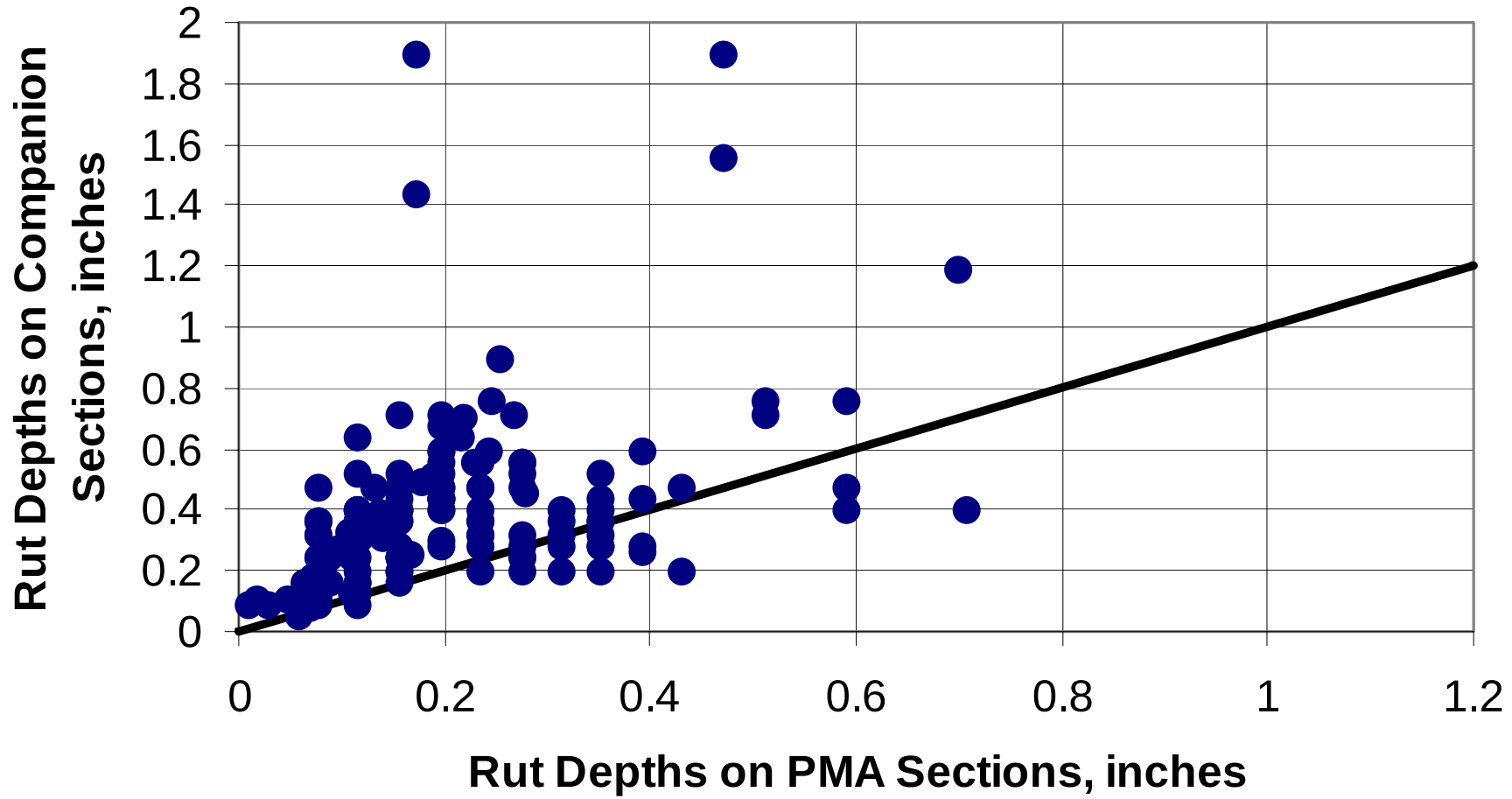
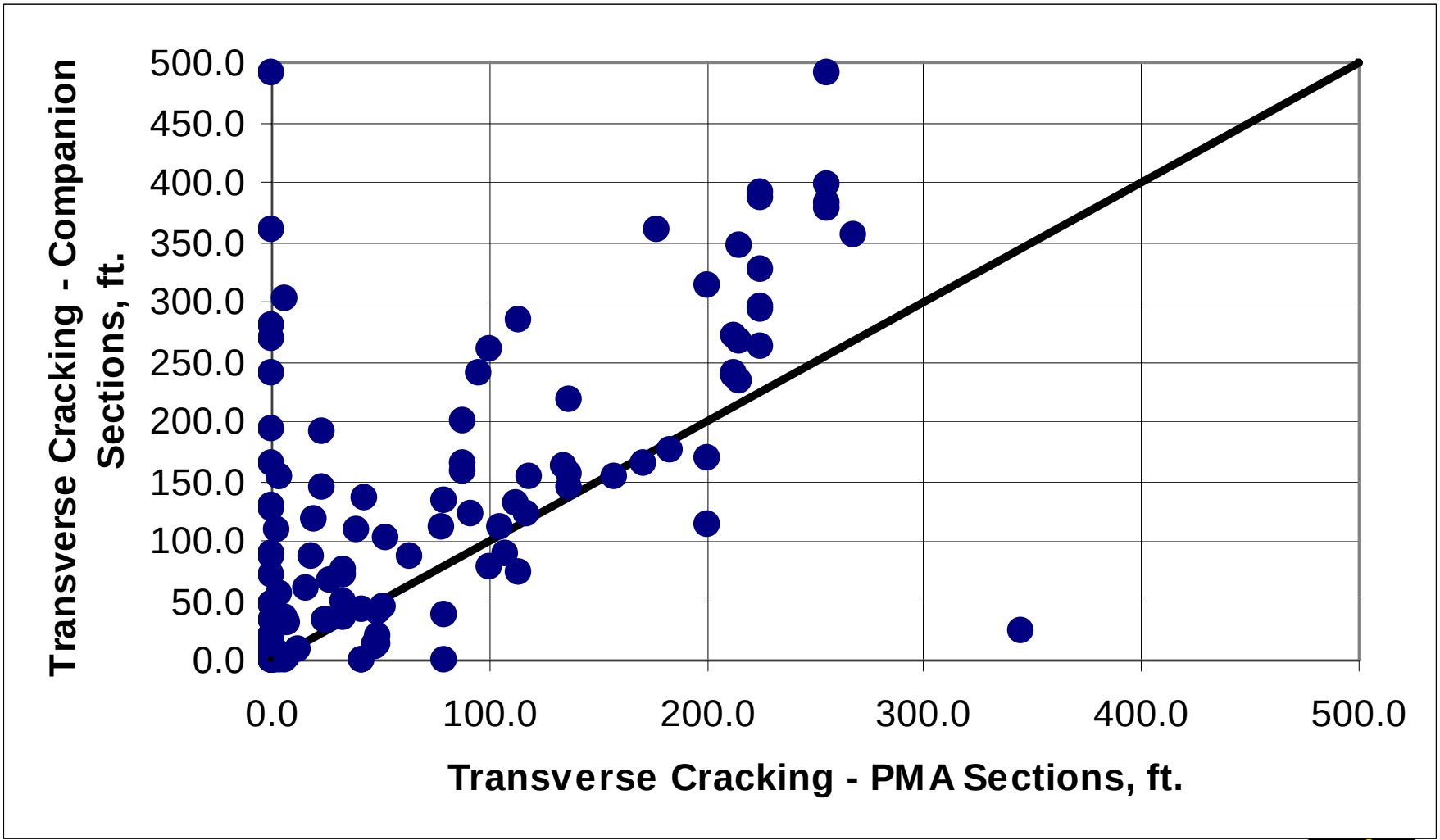
Pavement Cross Section	Foundation	Climate			
		Freeze		Non-Freeze	
		Wet	Dry	Wet	Dry
Thin HMA	Fine-Grained	2	2	4	3
	Coarse-Grained	3	3	3	3
Thick HMA	Fine-Grained	2	2	2	3
	Coarse-Grained	2	2	3	2
Full-Depth	Fine-Grained	0	1	2	2
	Coarse-Grained	0	1	2	2
HMA Overlays	HMA	3	3	6	6
	PCC	4	3	4	4
Total No. PMA + Companion Sections		16	17	26	25

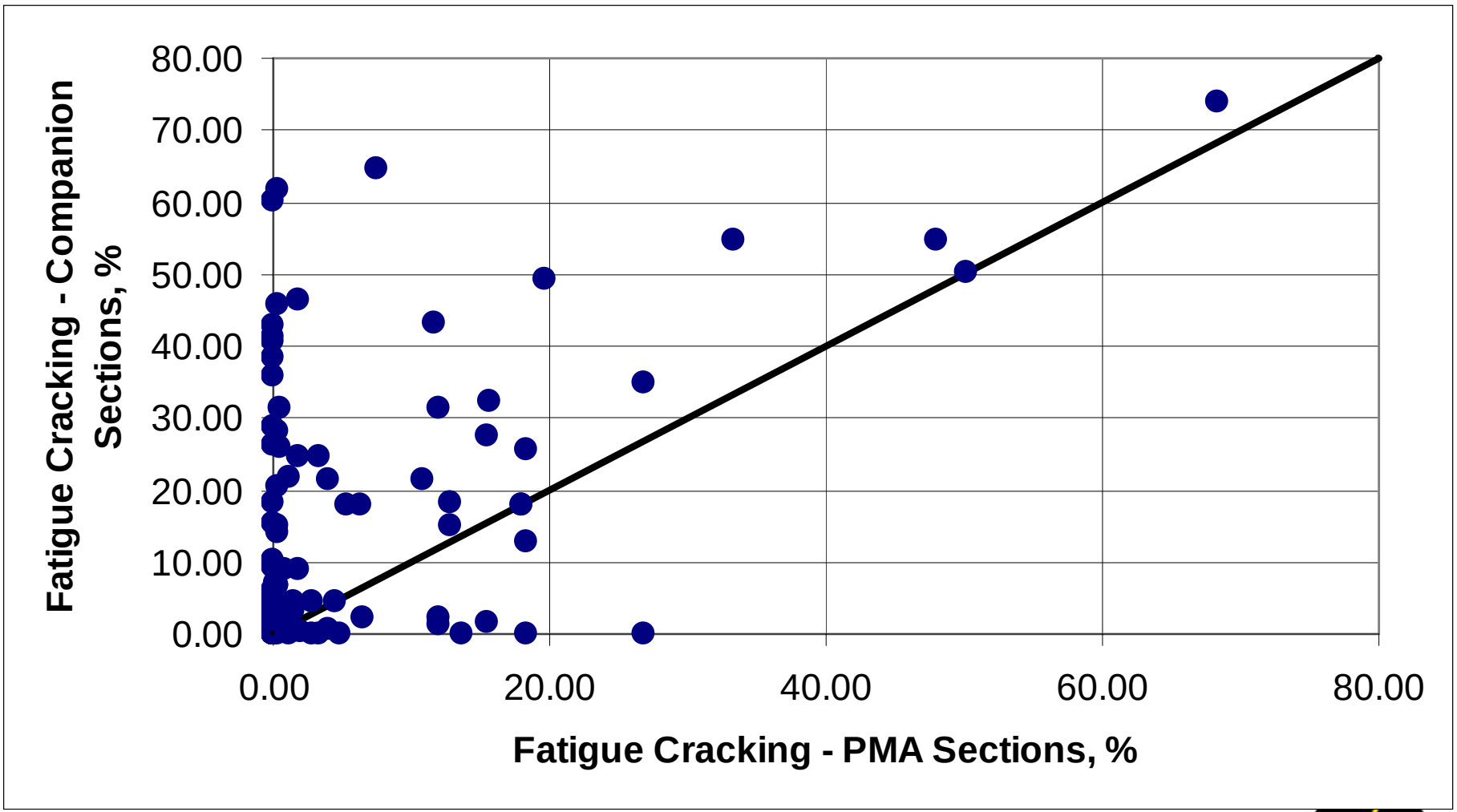
Direct Comparisons – Rutting



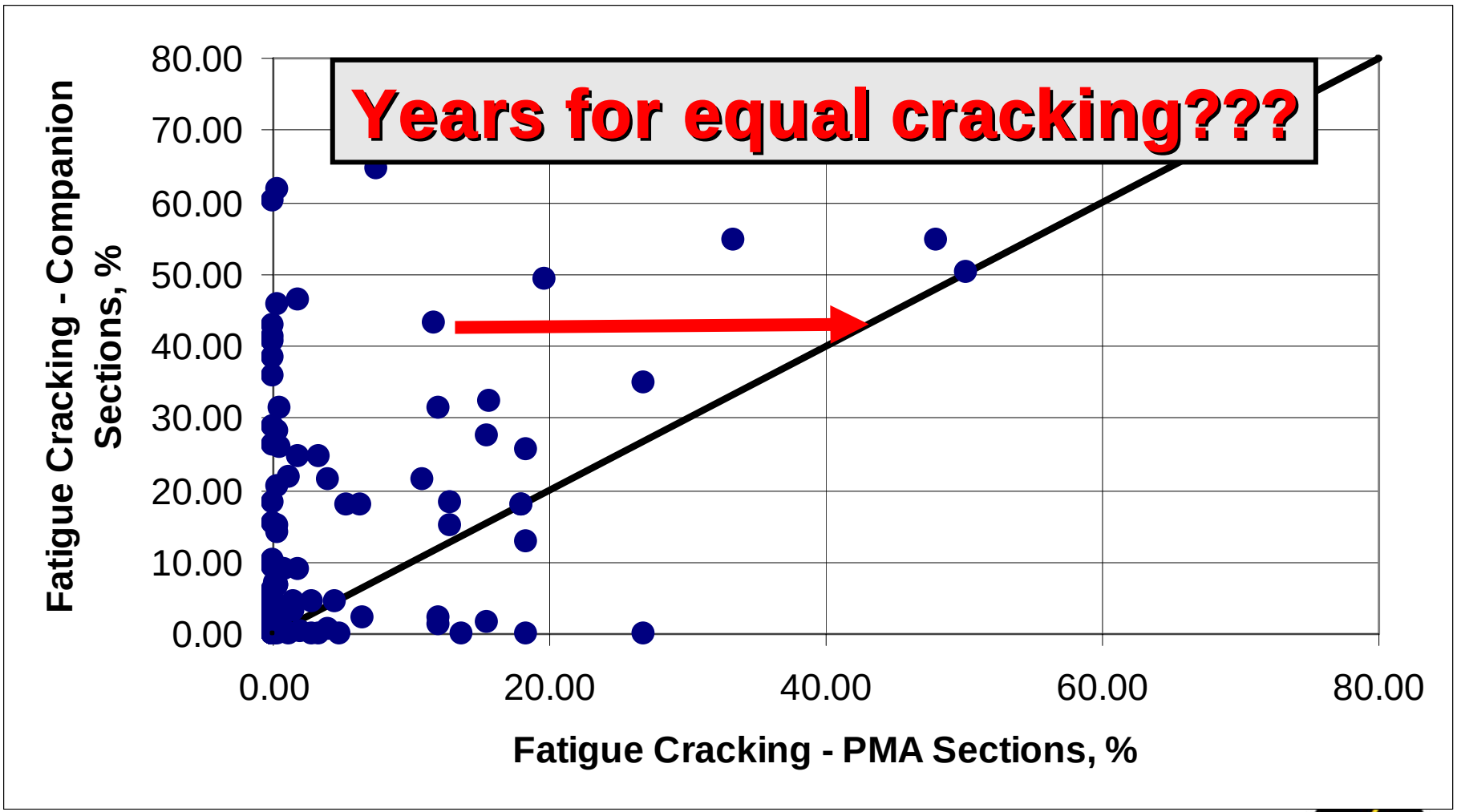
Distress Comparisons – Transverse Cracking



Distress Comparisons – Fatigue Cracking



Direct Comparisons Useful, But Still Have NOT Quantified Extended Service Life of PMA



Mechanistic-Empirical Analysis

- Use M-E distress prediction models from new 200x Pavement Design Guide for:
  - Fatigue Cracking
  - Rutting
- Damage indices computed using factorial cell specific calibration
- Compare damage indices to actual distress measurements for both PMA and unmodified sections

Summary of Expected Increase in Service Life, Years, Based on M-E Damage Based Analysis

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Site Factor	Condition Description		Added Life
Foundation	Non-expansive, coarse soils		5-10
	Expansive and plastic soils (PI>35)		2-5
	Frost Susceptible in cold climate		2-5
Water Table & Drainage	Deep		5-10
	Shallow; adequate		5-8
	Shallow; inadequate		0-2
Existing Pavement Condition	HMA	Good	5-10
		Poor-extensive cracking	1-3
	PCC	Good	3-6
		Poor-faulting & cracking	0-2

Continued:
Summary of Expected Increase in Service Life, Yrs

Site Factor	Condition Description		Added Life
Climate; Temp. Fluctuations	Hot	Hot Extremes	5-10
	Mild		2-5
	Cold	Cold Extremes	3-6
Traffic, Truck Volumes	Low	Intersections	5-10
		Thoroughfares	3-6
		Heavy Loads	5-10
	Moderate		5-10
	High		5-10

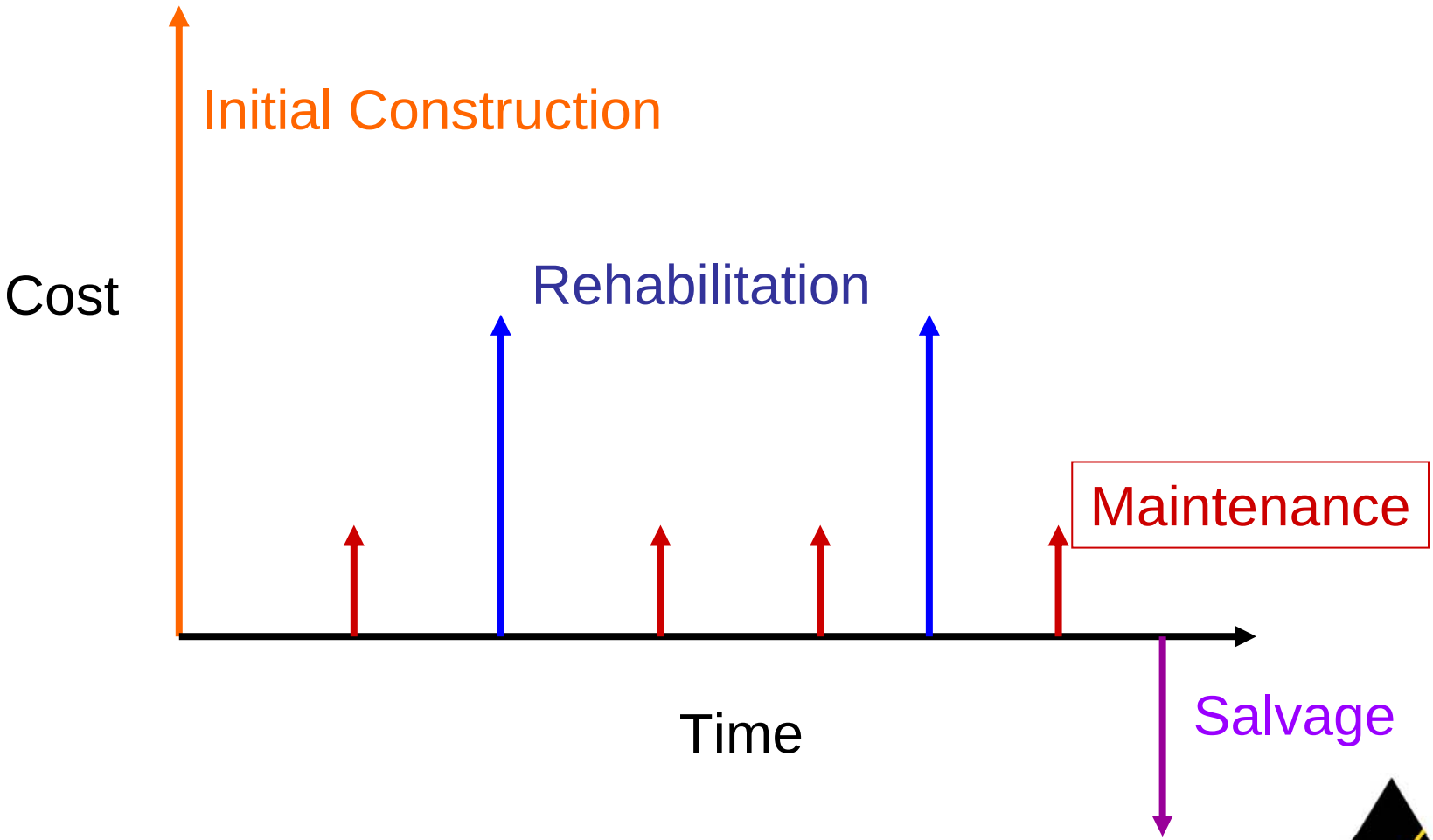
Generic LCCA Strategy/ Timeline and Revised PMA Timelines Based on Results

Years	5	10	15	20	25	30	35	40
Conv. Struct.	R. Maint.		R. Maint.		R. Maint.		R. Maint.	
		Mill-Fill		HMA Over.		Mill-Fill	HMA Over	
PMA Surface 2-4 in.		R. Maint.				RM		RM
				HMA Over.			HMA Over.	
PMA Full Depth			RM			RM		RM
				Mill-Fill			Mill-Fill	

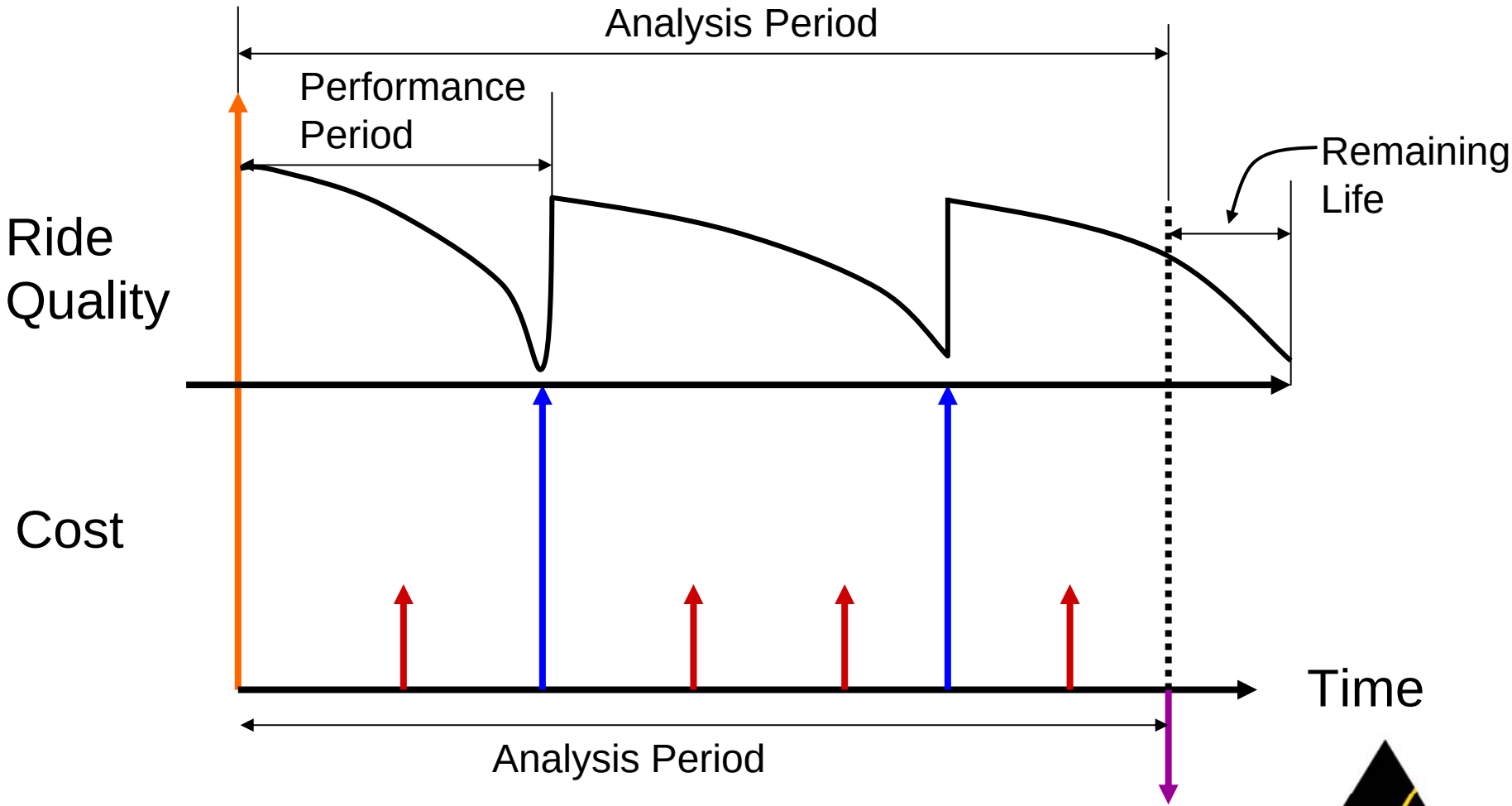
Purpose of Life Cycle Cost Analysis

- **Evaluate the overall long-term economic efficiency between competing alternative investment options.**

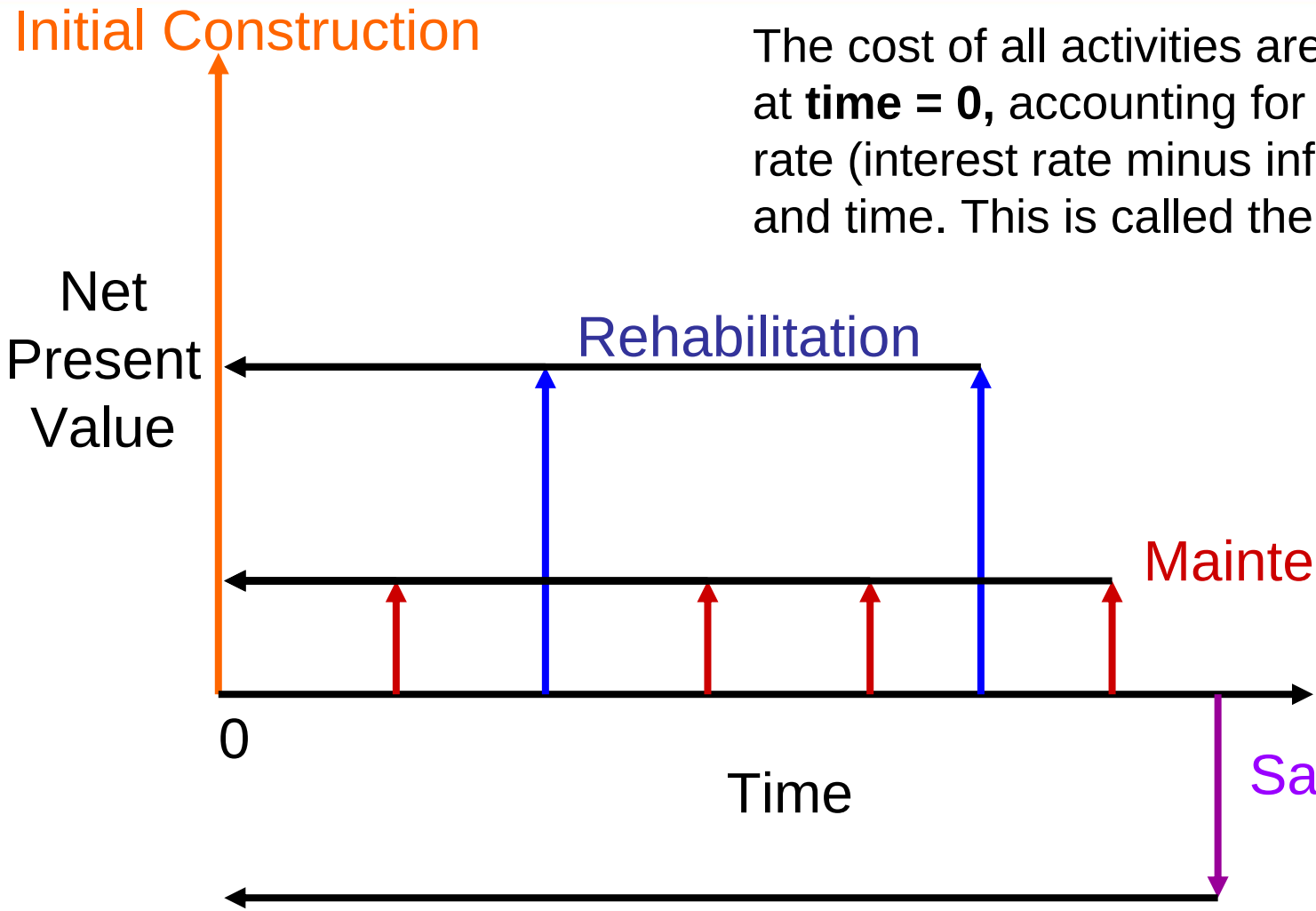
The Life Cycle



Performance

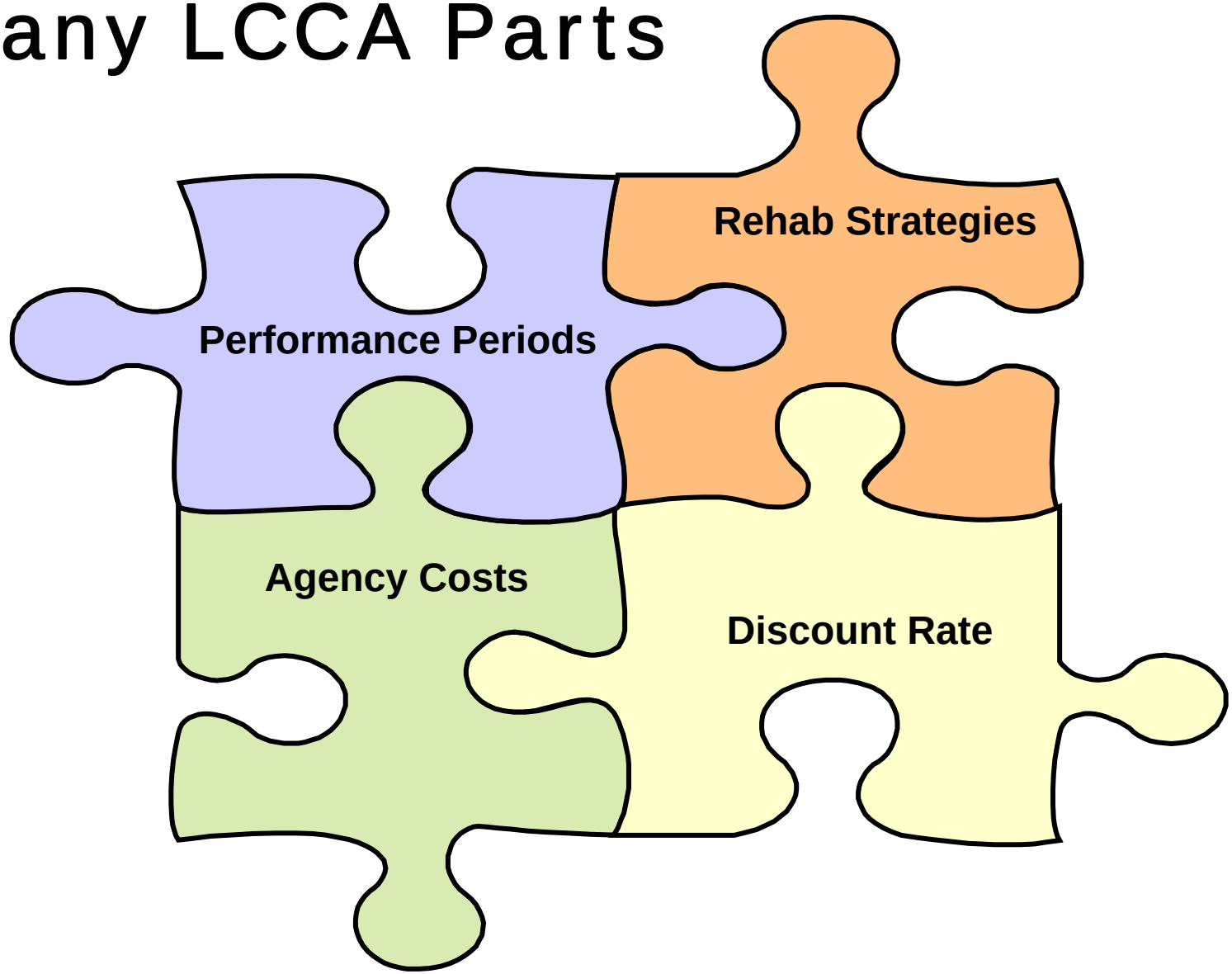


Net Present Value (NPV)



The cost of all activities are computed at **time = 0,** accounting for discount rate (interest rate minus inflation rate) and time. This is called the **NPV.**

Many LCCA Parts



Most Critical: initial cost and initial performance period

Typical Breakdown of NPV

40 yr. economic analysis, HMA Pavement

- **Initial Construction**
  - **65 to 85%**
- **All Overlays**
  - **10 to 30%**
- **Maintenance**
  - **3 to 5%**
- **Salvage Value**
  - **1 to 2%**

Economics of Using PMA

- Use LCCA to Evaluate Actual Cost/Savings with Enhanced Performance from PMA
- Examples to Follow, But…
- Each Agency Must Evaluate Using Own Inputs:
  - Prices, Performance Periods, Designs, Strategies, Discount Rates, User Costs, Etc

Assumptions for Following Examples

14.5" HMA Pavement	**Interest Rate: 4%**		**No User Costs Considered**	
	Analysis Period = 40 yrs.			
Prices				
Wearing (PG 64-22)	**$36/ton**	**$1.97/sy-in**		
Wearing (PG 76-22)	**$41/ton**	**$2.24/sy-in**		
Binder (PG 64-22)	**$35/ton**	**$1.91/sy-in**		
Binder (PG 76-22)	**$40/ton**	**$2.19/sy-in**		
Base (PG 64-22)	**$35/ton**	**$1.91/sy-in**		
Base (PG 76-22)	**$40/ton**	**$2.19/sy-in**		
Milling		**$1.40/sy**		
HMA Patching		**$36/sy**		
Quantities (per mile)				
Mainline: 2-lanes @ 12 ft ea.		**14,080sy**		
Shoulders: 1 @ 10 ft and 1 @ 4 ft		**8,212sy**		
References				
Prices from Maryland's "Pavement Selection Process"				
Maintenance from "Pa DOT Pub. 242, Pavement Policy Manual"				
Performance Scenarios are Examples from "Quantifying Effects of PMA ..."				

EXAMPLE 1, Unmodified All Layers

Year	Construction Item and/or Material	Quantity	Unit	Cost/Unit
0	10" HMA Base (3 - 10 EAL)	14080	sy	$ 19.10
0	2.5" HMA Binder (3 - 10 EAL)	14080	sy	$ 4.78
0	2" HMA Wearing (3 - 10 EAL)	14080	sy	$ 3.94
0	10" HMA Base (0.3 - 3 EAL)	8212	sy	$ 19.10
0	2.5" HMA Binder (0.3 - 3 EAL)	8212	sy	$ 4.78
0	2" HMA Wearing (0.3 - 3 EAL)	8212	sy	$ 3.94
0	Maint. & Protection of Traffic @2.3%	1	ls	$14,264
0	Mobilization @5.5%	1	ls	$34,109
10	Deep Patch 1% (mainline)	141	sy	$ 36.00
10	Mill 2" (mainline)	14080	sy	$ 1.40
10	2" hma overlay (mainline)	14080	sy	$ 3.94
10	Maint. & Protection of Traffic @2.3%	1	ls	$ 1,846.05
10	Mobilization @5.5%	1	ls	$ 4,414.48
18	Mill 2"	22292	sy	$ 1.40
18	Deep Patch 3% (mainline)	422	sy	$ 36.00
18	#60 scratch course	422	ton	$ 36.00
18	2.5" hma overlay (binder)	14080	sy	$ 4.78
18	2" hma overlay (wearing)	14080	sy	$ 3.94
18	#60 scratch course	246	ton	$ 36.00
18	2.5" hma overlay (binder)	8212	sy	$ 4.78
18	2" hma overlay (wearing)	8212	sy	$ 3.94
18	Maint. & Protection of Traffic @2.3%	1	ls	$6,091
18	Mobilization @5.5%	1	ls	$14,566
28	Same Scenario as Year 10	1	ls	$86,524
34	SameScenario as Year 18	1	ls	$285,492
20	Total Annual Maintenance ($1825/yr)	40	yr	$ 1,825.00
				Total

Yr.	Activity	Cost,$	NPW,$
0	10” Base 2.5” Binder 2” Wearing	668K	668K
10	2” mill/fill 1% patching (not on shoulders)	87K	58K
18	2” mill 3% patching scratch 2.5” Binder 2” Wearing (incl. shoulders)	285K	141K
28	Same as yr.10	87K	29K
34	Same as yr.18	285K	75K
Annual	Maint ($1.8K/yr)	73K	33K
	Total NPW:		1,005K

EXAMPLE 2, Modified Wearing Course

(top 2", including shoulders)

Year	Construction Item and/or Material	Quantity	Unit	Cost/Unit
0	10" HMA Base (3 - 10 EAL)	14080	sy	$ 19.10
0	2.5" HMA Binder (3 - 10 EAL)	14080	sy	$ 4.78
0	2" HMA Wearing (3 - 10 EAL)	14080	sy	$ 4.48
0	10" HMA Base (0.3 - 3 EAL)	8212	sy	$ 19.10
0	2.5" HMA Binder (0.3 - 3 EAL)	8212	sy	$ 4.78
0	2" HMA Wearing (0.3 - 3 EAL)	8212	sy	$ 4.48
0	Maint. & Protection of Traffic @2.3%	1	ls	$14,541
0	Mobilization @5.5%	1	ls	$34,771
18	Mill 2"	22292	sy	$ 1.40
18	Deep Patch 3% (mainline)	422	sy	$ 36.00
18	#60 scratch course	422	ton	$ 36.00
18	2.5" hma overlay (binder)	14080	sy	$ 4.78
18	2" hma overlay (wearing)	14080	sy	$ 4.48
18	#60 scratch course	246	ton	$ 36.00
18	2.5" hma overlay (binder)	8212	sy	$ 4.78
18	2" hma overlay (wearing)	8212	sy	$ 4.48
18	Maint. & Protection of Traffic @2.3%	1	ls	$6,368
18	Mobilization @5.5%	1	ls	$15,228
34	SameScenario as Year 18	1	ls	$298,469
20	Total Annual Maintenance ($1825/yr)	40	yr	$ 1,825.00
				Total

Yr.	Activity	Cost,$	NPW,$
0	10" Base 2.5" Binder 2" Wearing	682K	682K
18	2" mill 3% patching scratch 2.5" Binder 2" Wearing (incl. shoulders)	298K	147K
34	Same as yr.18	298K	79K
Annual	Maint ($1.8K/yr)	73K	33K
	Total NPW:		941K

EXAMPLE 3, Perpetual Pavement: Modified Wearing Course (top 2”) and Bottom 4” of Base (incl. shoulders)

Interest
4

Year	Construction Item and/or Material	Quantity	Unit	Cost/Unit
0	4" HMA Modified Base (3 - 10 EAL)	14080	sy	$ 8.76
0	6" HMA Base (3 - 10 EAL)	14080	sy	$ 11.46
0	2.5" HMA Binder (3 - 10 EAL)	14080	sy	$ 4.78
0	2" HMA Wearing (3 - 10 EAL)	14080	sy	$ 4.48
0	4" HMA Base (0.3 - 3 EAL)	8212	sy	$ 8.76
0	6" HMA Base (3 - 10 EAL)	8212	sy	$ 11.46
0	2.5" HMA Binder (0.3 - 3 EAL)	8212	sy	$ 4.78
0	2" HMA Wearing (0.3 - 3 EAL)	8212	sy	$ 4.48
0	Maint. & Protection of Traffic @2.3%	1	ls	$15,115
0	Mobilization @5.5%	1	ls	$36,144
18	Mill 2"	22292	sy	$ 1.40
18	2" hma overlay (wearing)	14080	sy	$ 4.48
18	2" hma overlay (wearing)	8212	sy	$ 4.48
18	Maint. & Protection of Traffic @2.3%	1	ls	$3,015
18	Mobilization @5.5%	1	ls	$7,209
34	SameScenario as Year 18	1	ls	$141,301
20	Total Annual Maintenance ($1825/yr)	40	yr	$ 1,825.00
				Total

Yr.	Activity	Cost,$	NPW,$
0	10” Base 2.5” Binder 2” Wearing	709K	709K
18	2” mill/fill (incl. shoulders)	141K	70K
34	Same as yr.18	141K	37K
Annual	Maint ($1.8K/yr)	73K	33K
	Total NPW:		849K

Summary - PMA Costs and LCC Savings

Pavement Type	Initial Cost	Change[#]	NPV	Savings
1) Unmodified (resurface yr.10 and 28, structural overlay yr.18 and 34)	669K	-	1,005K	-
2) Modified Wearing (structural overlay yr.18 and 34)	682K	+ 2.0%	941K	6.5%
Extra) Modified Wearing and Binder (structural overlay yr.18 and 34)	698K	+ 4.5%	964K	4.5%
3) Modified Wearing & Base (Perpetual Pavement: resurface yr. 18 and 34)	709K	+ 6.0%	849K	15.5%
Extra) Modified Wearing, Binder & Base (Perpetual Pavement: resurface yr. 18 and 34)	725K	+ 8.5%	864K	14.0%

Note: Modified mainline and shoulders

[#] **Cost to use PMA equates to approx. 1% of initial cost per inch modified**


Polymer Modified Asphalt - Performance and True Economics
Questions?

APA Studies/ Reports on Pavement Performance or Life Cycle Cost Analysis

Performance Study of New Flexible Pavements

- By Harold Von Quintus and Associates for APA
- 362 LTPP test sections used.
  - Median age of 17 yrs.
- Determined average time to various magnitudes of distress.
  - Fatigue cracking, longitudinal cracking in wheel-path, longitudinal cracking outside w-p, transverse cracking, rut depth, smoothness
- Concluded that average service life was 20+ years before structural rehab required.

Four-page Summary of Same Study (for APA).

- Similar style to FHWA's TechBrief RD-00-165: *Performance Trends of Rehabilitated AC Pavements.*
  - Performance Study of AC Overlays
  - 125 LTPP overlay sections
  - Summary: "Clearly, the majority of the AC overlays included in the LTPP database have served for 15 years or more before load and non-load related distresses became sufficient to require rehabilitation."

Pavement Life-Cycle Cost Studies Using Actual Cost Data – A Synthesis

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- By Jorge Villacres for APA
- Ohio, Kansas and Iowa studies
- Direct comparisons between HMA and PCC
- Determined actual costs for all work over given time using historical data from agency records
- Results
  - Ohio: HMA had lower LCC in 5/5 cases
  - Kansas: HMA had lower LCC in 10/11 cases
  - Iowa: HMA had lower LCC in 2/3 cases


The End
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Questions?