ODOT Preventive Maintenance Process Analysis

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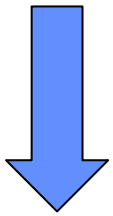
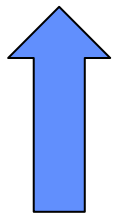
APPLIED RESEARCH ASSOCIATES, INC.

An Employee-Owned Company

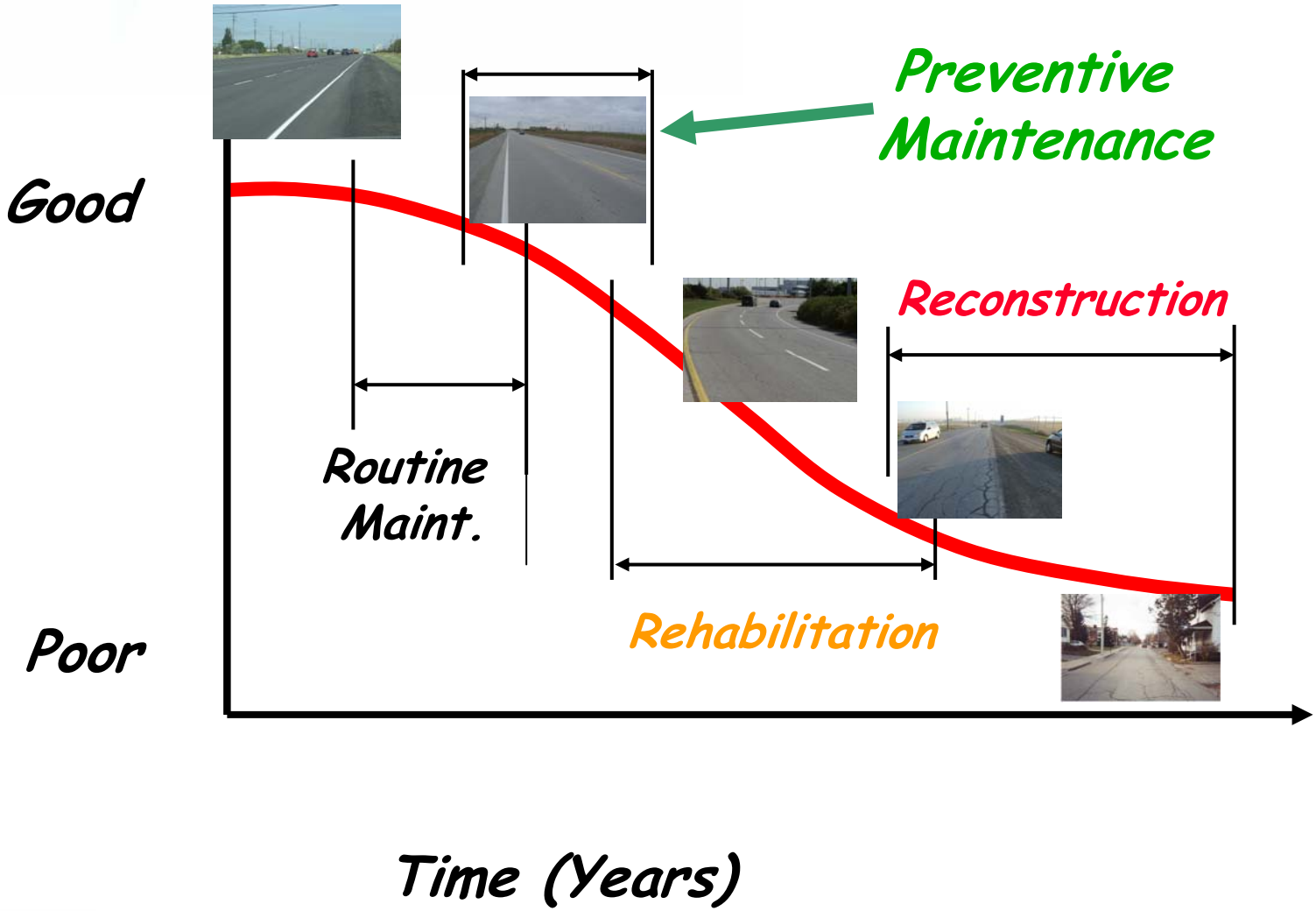
Pavement Preservation Defined

"Is the sum of all activities undertaken to provide and maintain serviceable roadways, including preserving the investment, extending service life, enhancing performance, ensuring cost-effectiveness and reducing user delays."

Preventive Maintenance

- Preventive not reactive maintenance
-  Deterioration =  Life
- Very cost-effective
- Applicable for all pavements
- Right treatment, right pavement, right time
- Importance of life-cycle cost analysis

Pavement Condition Vs Time



Pavement Preservation

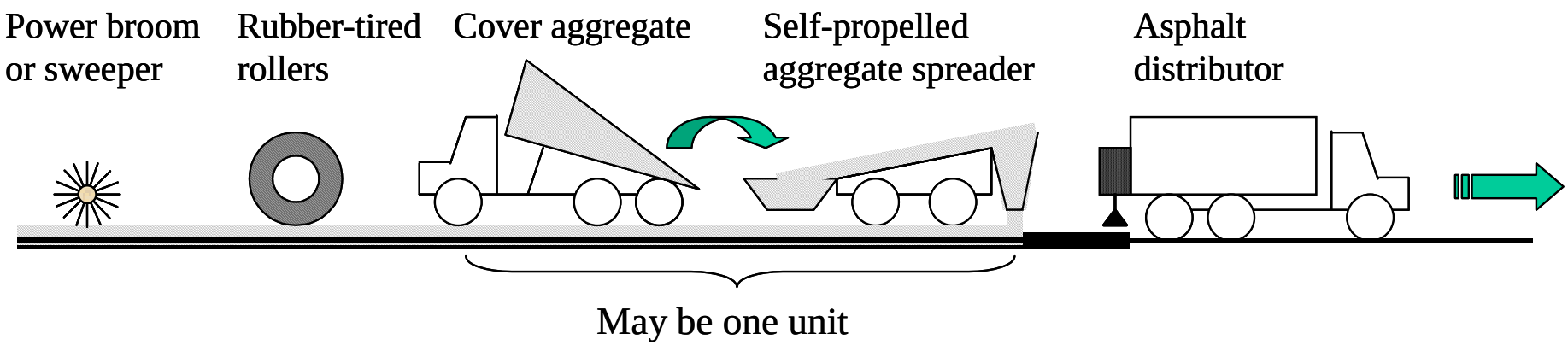
Pavement Preservation Guidelines					
	Type of Activity	Increase Capacity	Increase Strength	Reduce Aging	Restore Serviceability
	New Construction	X	X	X	X
	Reconstruction	X	X	X	X
	Major (Heavy) Rehabilitation		X	X	X
	Structural Overlay		X	X	X
Pavement Preservation	Minor (Light) Rehabilitation			X	X
	Preventive Maintenance			X	X
	Routine Maintenance				X
	Corrective (Reactive) Maintenance				X
	Catastrophic Maintenance				X

Crack Treatments

- **Prevents water and debris from entering individual cracks in the HMA pavement surface**

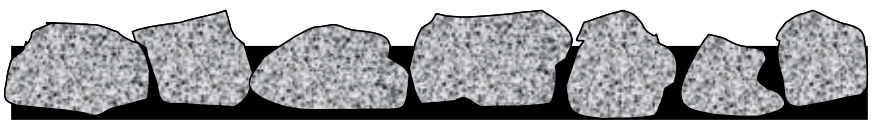
Chip Seal

- Provide wearing course
- Improve surface friction
- Seal pavement surface from water penetration
- Lower maintenance, eliminate dust



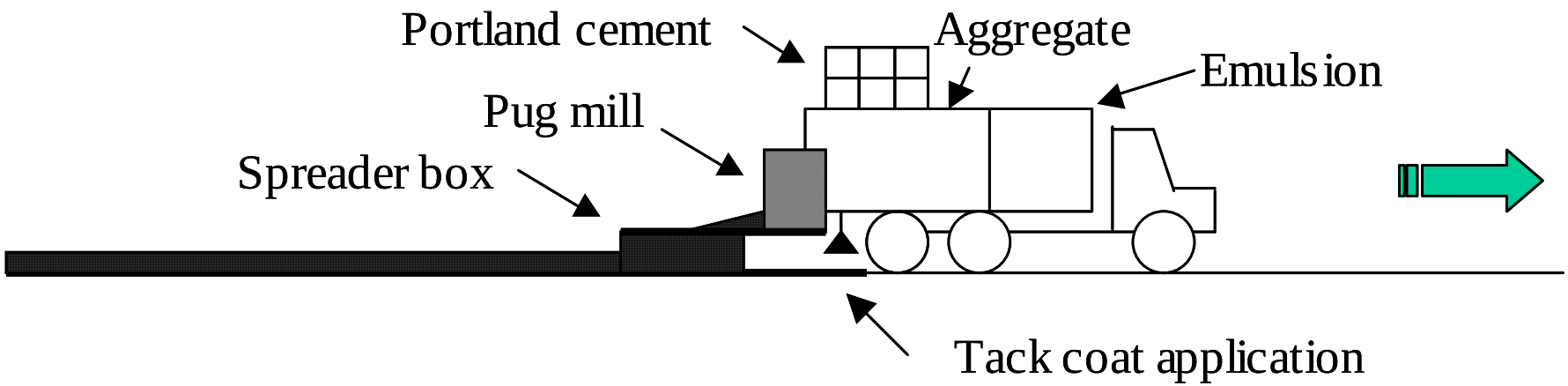
Chip Seal

Chip Seal



Slurry Seal

- **A mixture of emulsified asphalt, graded fine aggregate, mineral filler, and water, mixed and uniformly spread over the pavement surface**
- **Applied cold to pavement surface**



Slurry Seal

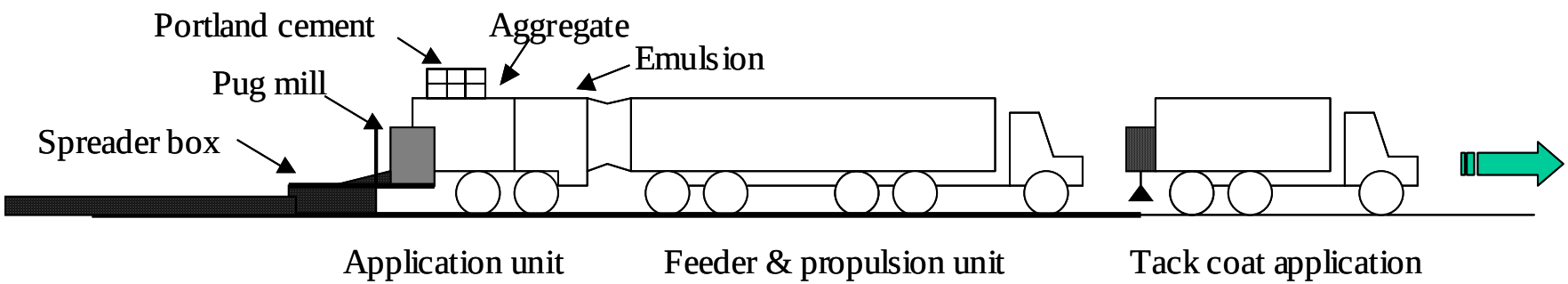
- Seal pavement surface
- Retard surface raveling
- Improved surface friction

Microsurfacing

- **Similar to slurry seal**

  BUT…..

- **Larger and higher quality aggregate**
- **Emulsion contains modifiers**

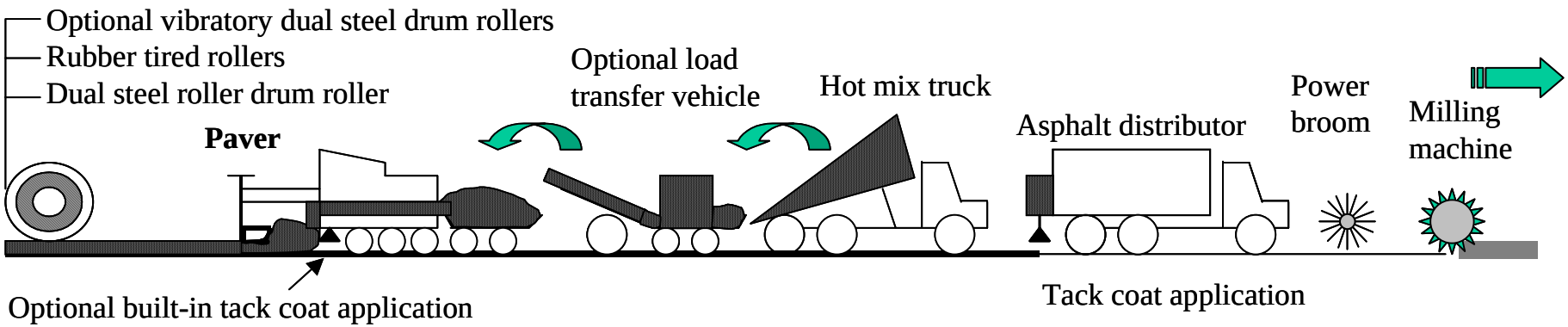


Microsurfacing

Microsurfacing

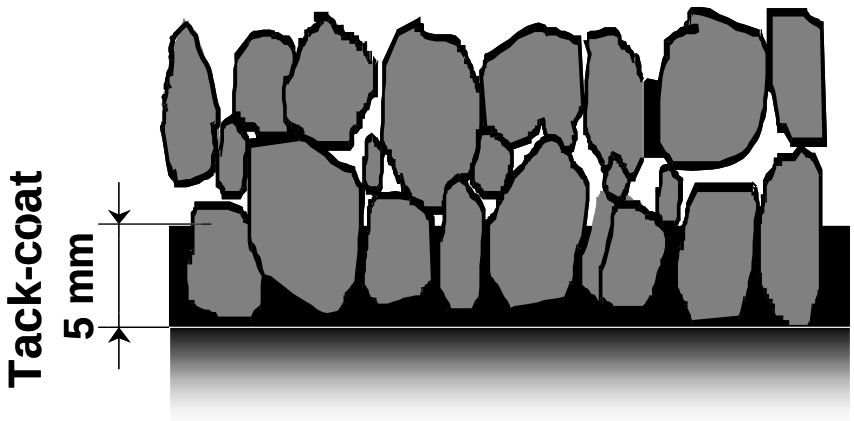
- Level pavement surface
- Fill ruts
- Restore surface friction

Nova Chip®


Optional vibratory dual steel drum rollers
Rubber tired rollers
Dual steel roller drum roller
Paver
Optional load transfer vehicle
Hot mix truck
Asphalt distributor
Power broom
Milling machine
Optional built-in tack coat application
Tack coat application

Nova Chip®

- Gap graded HMA
- Heavy tack coat applied first
- Proprietary machine and process
- Paver applies both tack coat and HMA
- Functional, not a structural overlay



Thin HMA Surfacing

Types of Smoothseal

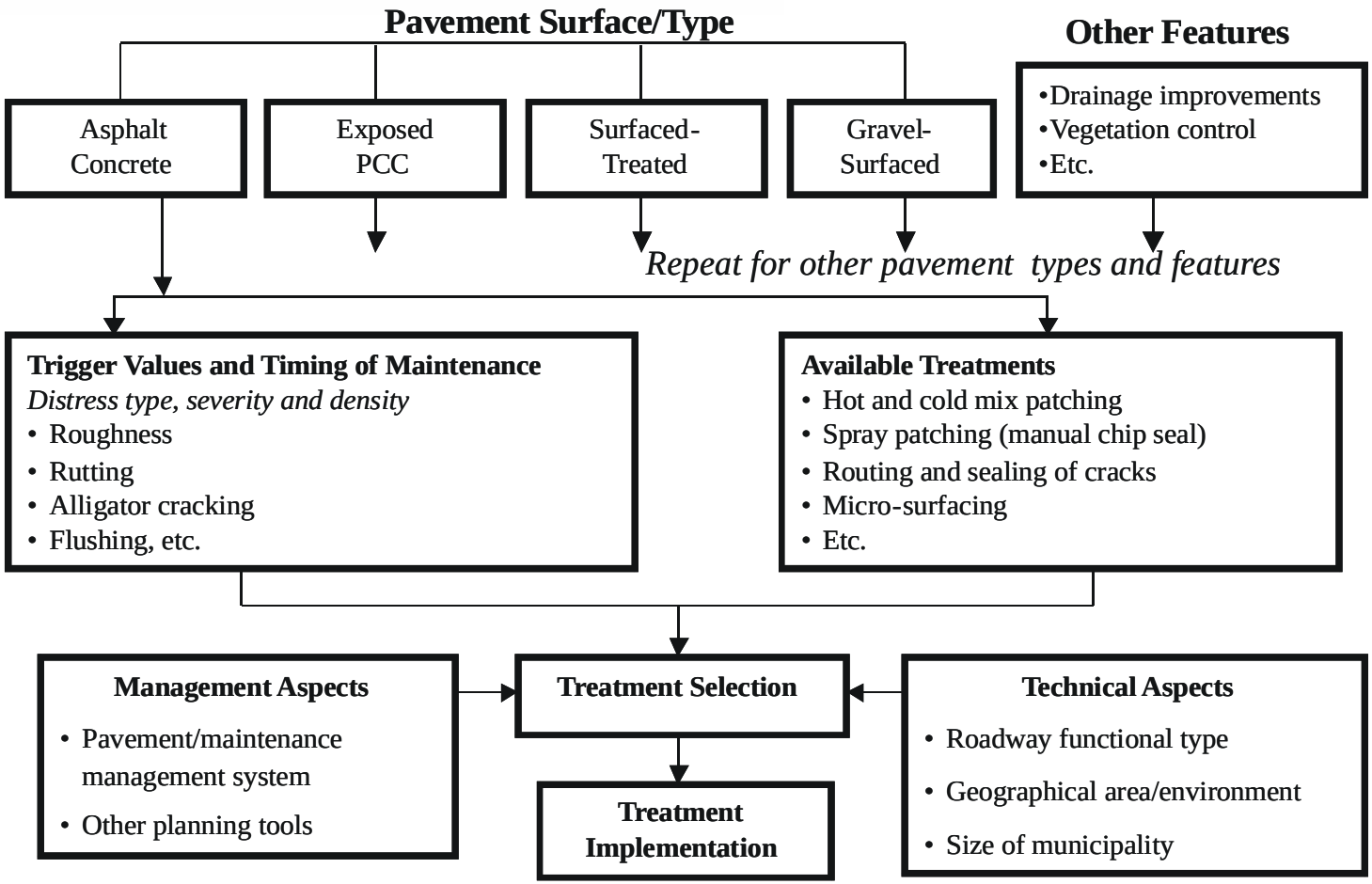
Purpose and Application

- Provide a new wearing surface
- Seal cracks in the surface
- Waterproof the surface
- Improve pavement surface friction and surface drainage

Purpose and Application

- Slow pavement weathering and aging
- Improve the surface appearance
- Provide visual delineation between the mainline pavement and the shoulder

ODOT Preventive Maintenance Process Analysis



Objectives

- **Evaluation of the performance of various pavement preventive maintenance treatments used in Ohio including:**
  - **Chip Seal**
  - **Microsurfacing**
  - **Ultrathin bonded overlay – Novachip**
  - **Smoothseal (PMAC)**
  - **Thin HMAC overlays with repairs**
  - **Thin HMAC overlays without repairs**

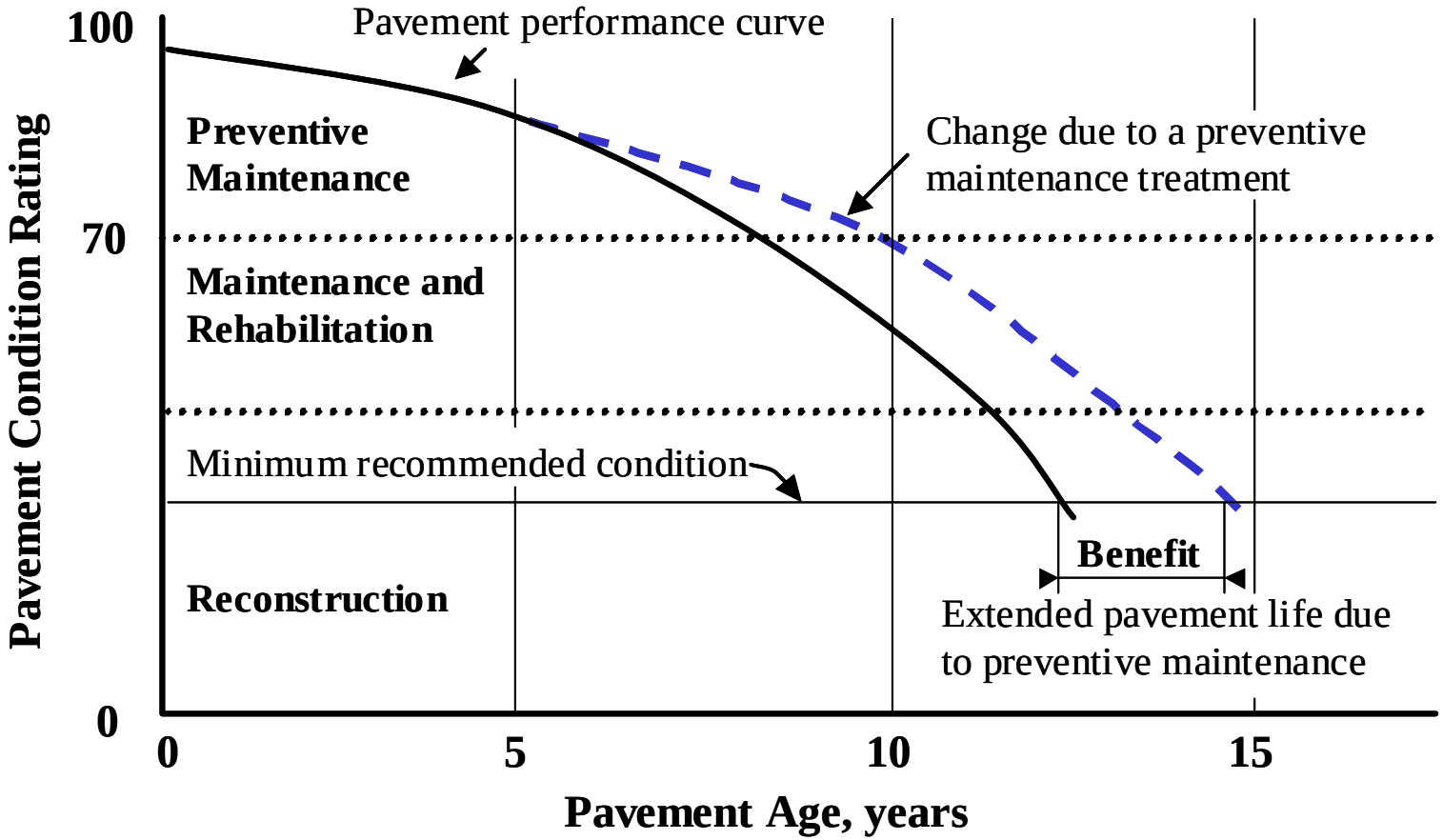
Objectives

- Evaluation of the performance of crack sealing in Ohio
- Analysis of the cost of performing various treatments (typical costs and variability)
- Cost-effectiveness/cost-benefit of individual PM treatments
- Evaluation of applicability of PM treatments, for roadway classes, age and surface condition
- Documentation of perspective of interested parties

Limitations

- Convenience characteristics such as noise, user delay, safety (skid and accident rates) excluded due to difficulty in assigning benefits and costs
- Pavement smoothness impact excluded due to limited availability of field performance data
- Cost-effectiveness to be based on pavement condition rating (PCR)
- Concrete pavement restoration to be excluded due to the limited project data available

Benefits of Preventive Maintenance



Data Sources

- ODOT Pavement Management System
- Central office administered PM projects
- ODOT and district costs databases
- ODOT District interviews
- Site visits by ARA
- Meetings and discussions with industry and interested party representatives

Data Collected

- Pavement surface condition prior to PM treatment
- Condition ratings immediately before treatment and since treatment
- Construction item information
- Construction cost data

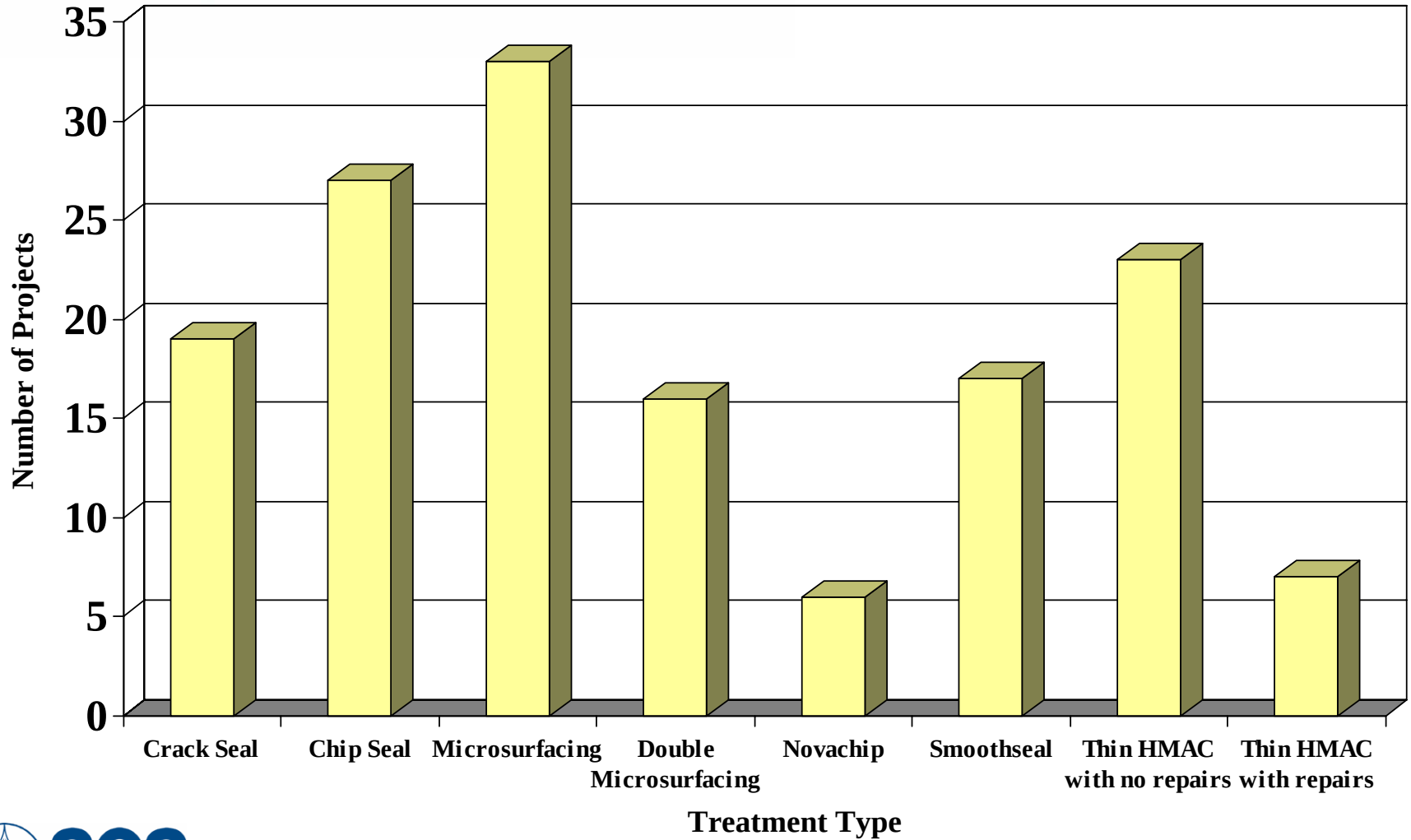
Project Grouping

- **Tier 1 – Projects included in the ODOT PMIS database since the start of the formal PM process in 2001**
- **Tier 2 – Sections included in the ODOT PMIS database since 1984 which satisfied the PM requirements matrix but were not specifically labeled as PM projects**
- **Tier 3 – Specific PM trial projects completed in 2004/2005**
- **Control projects – flexible and composite pavements built/repaired since 1985**

Tier 1 Projects

- 192 projects in ODOT PMIS labeled as “PM”
- Most between 1999 and 2004
- 148 projects usable for analysis
- Some of these will come back into play when database is updated because of lag time between:
  - Award date
  - Construction
  - PCR measurement
  - Database update

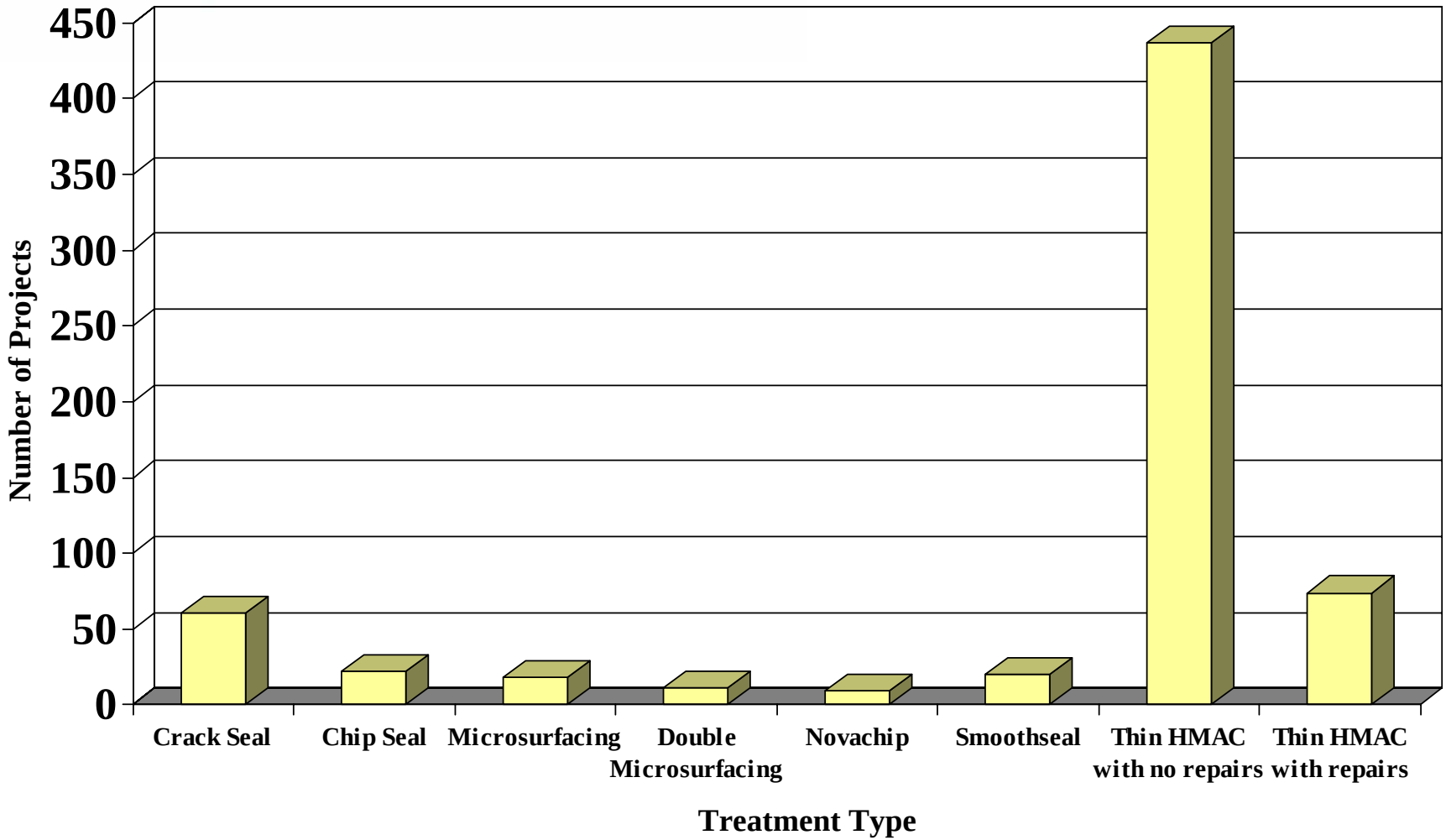
Tier 1 PM Sections by Treatment Type



Tier 2 Projects

- ODOT PMIS Database
- Projects with a PM treatment
  - Satisfied all the current criteria for that PM treatment (such as PCR range and distresses) for the year or 2 years prior to the treatment
- Between 1985 and 2004
- After filtering - 652 projects usable for analysis

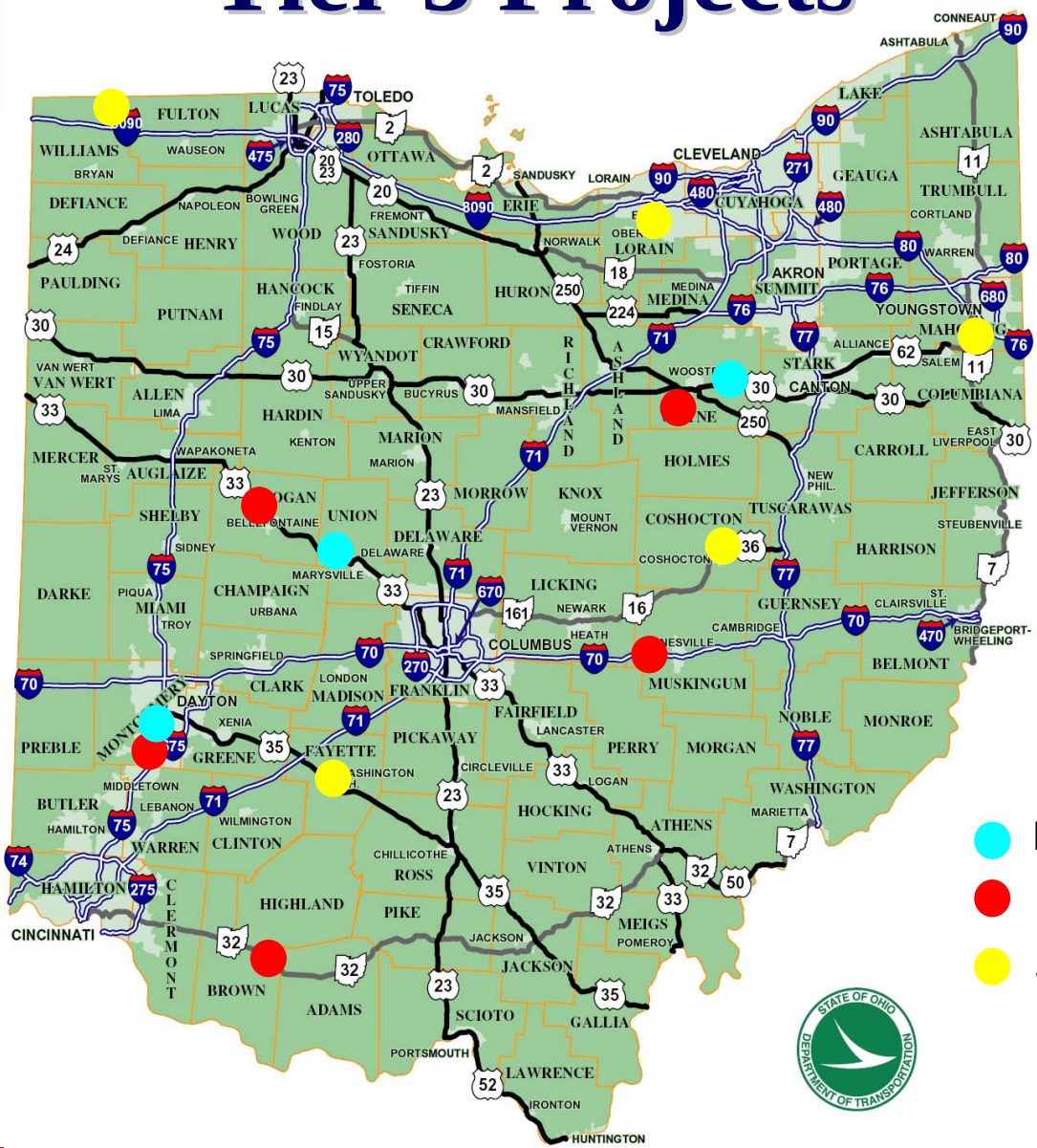
Tier 2 PM Sections by Treatment Type



Tier 3 Projects

- Central Office $ 5 Million and $2.5 Million PM Program Projects
- 10 projects constructed in 2004
  - 4 Microsurfacing
  - 3 NovaChip
  - 3 Smoothseal
- 3 projects constructed in 2005
  - 1 Microsurfacing
  - 2 Smoothseal

Tier 3 Projects



Tier 3 Projects

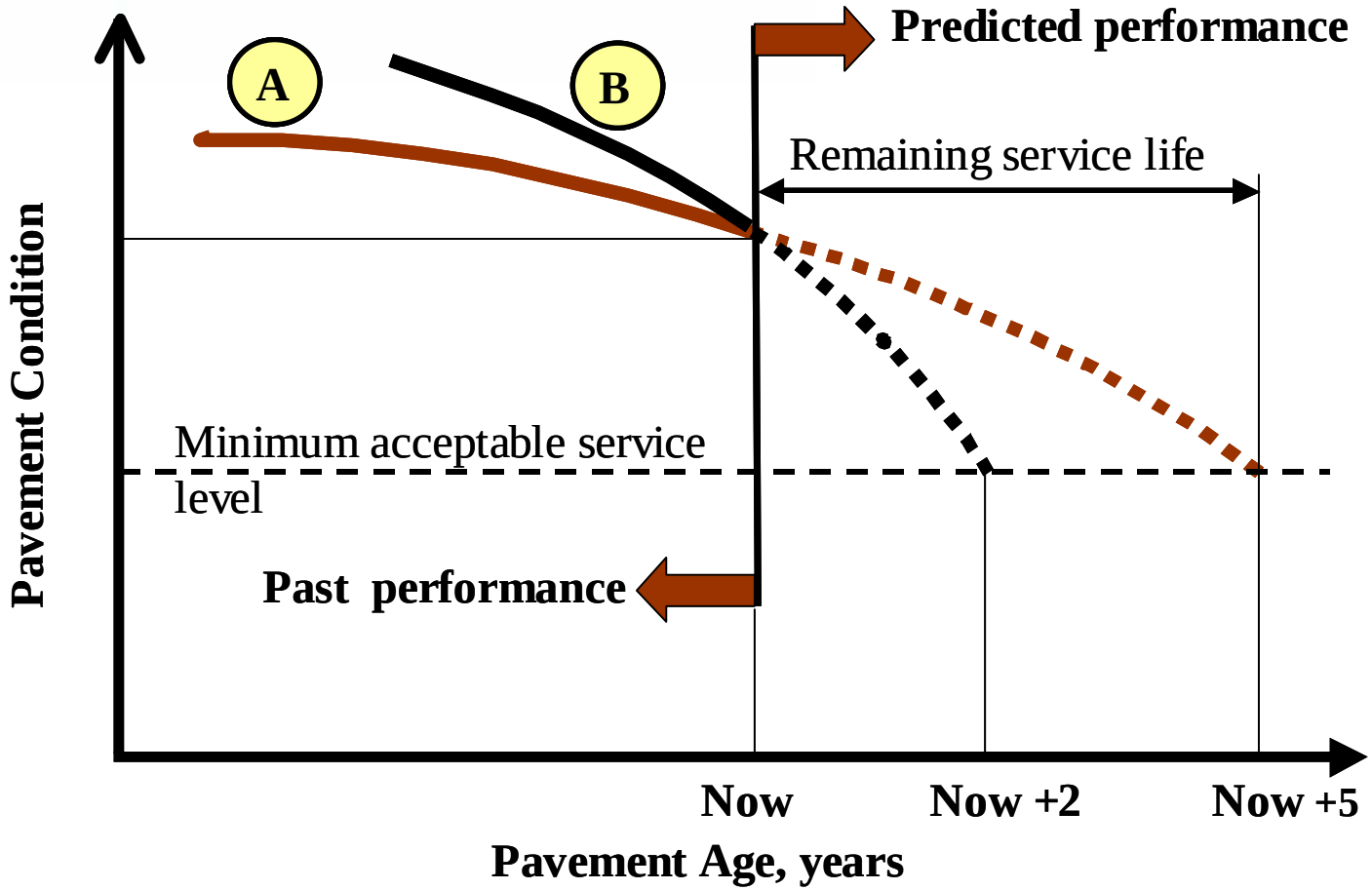
District 3: WAY-30-22.89 (2004)
NovaChip®

District 5: MUS-70-0.76 (2004)
Microsurfacing

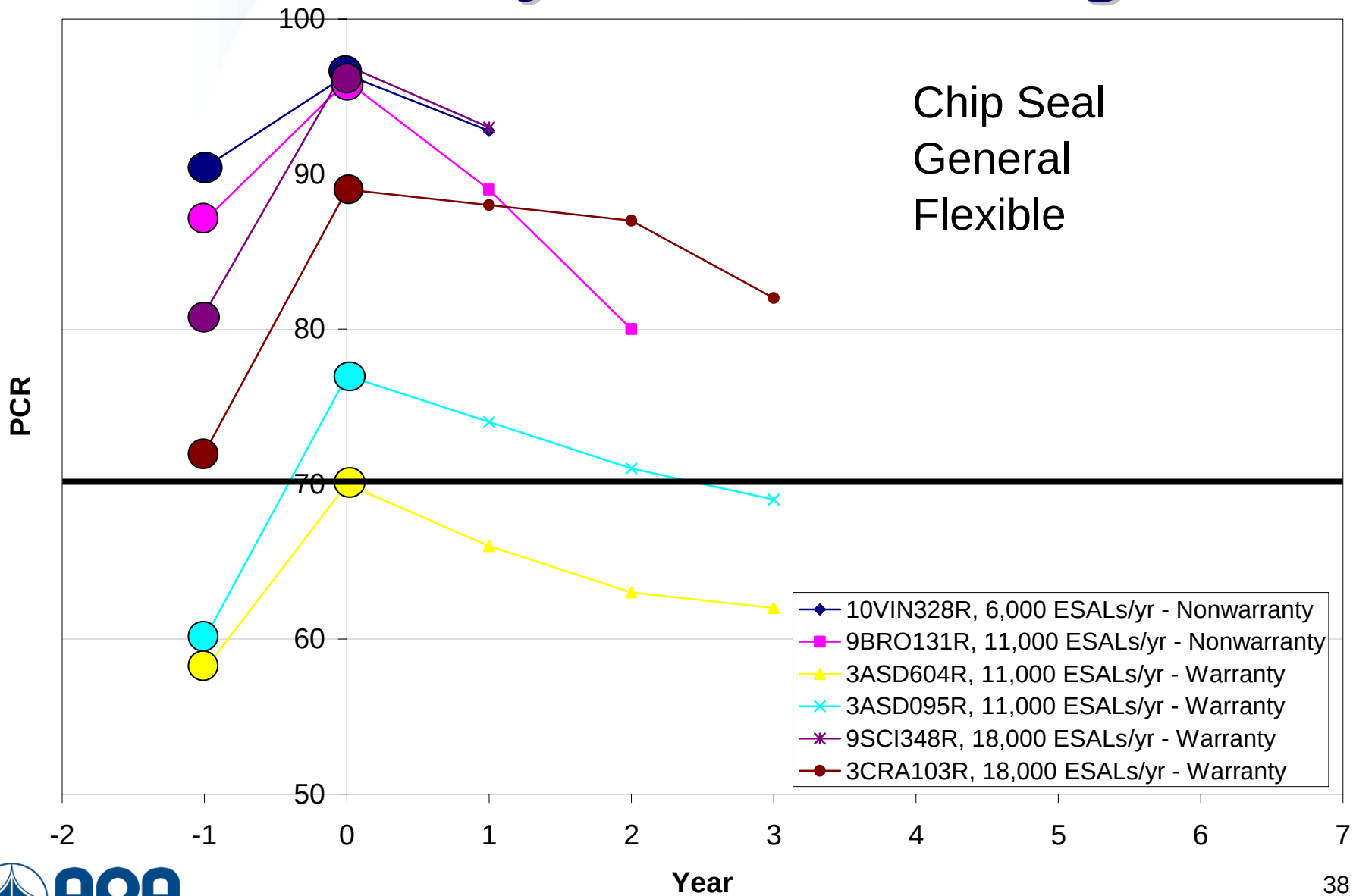
Control Projects

- ODOT PMIS Database
- Flexible and Composite Pavements since 1985
- Increase in PCR < 5 (no treatment)
- 609 HMAC Overlays (> 2 in) without Repairs
- 210 HMAC Overlays with Repairs
- 120 New Flexible Pavements

Goal of Prediction Modeling



Tier 1 Projects: PCR vs. Age



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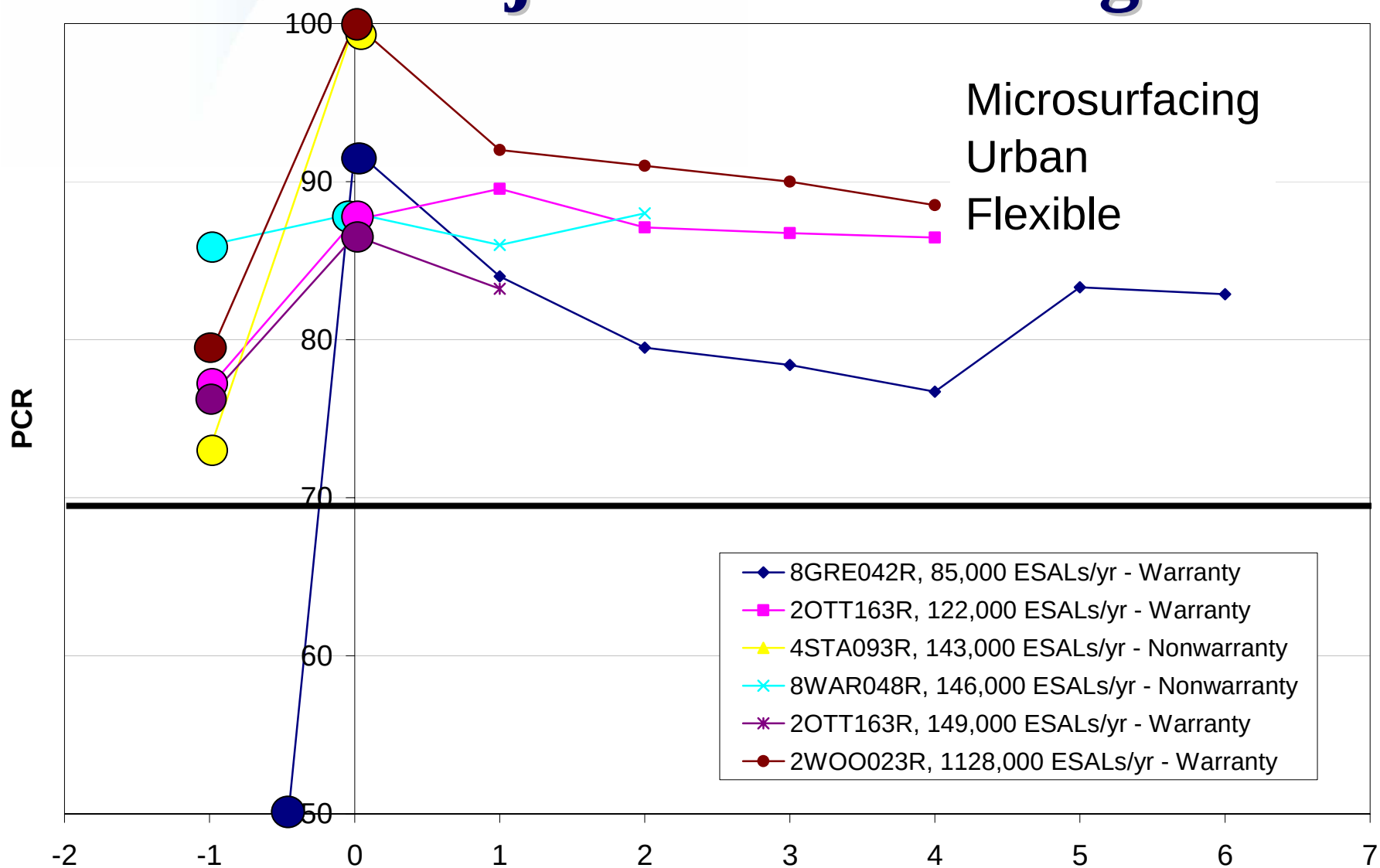

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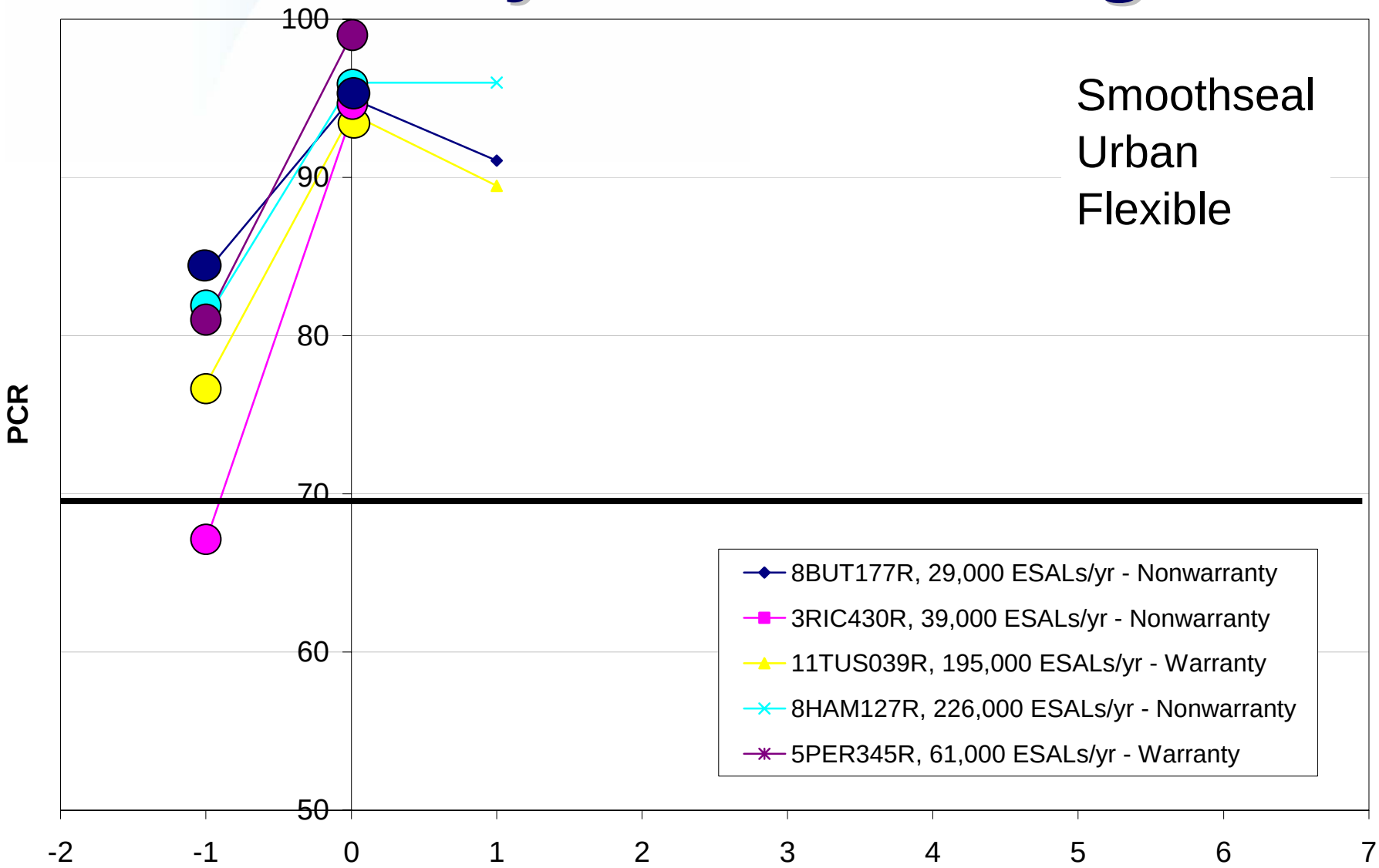
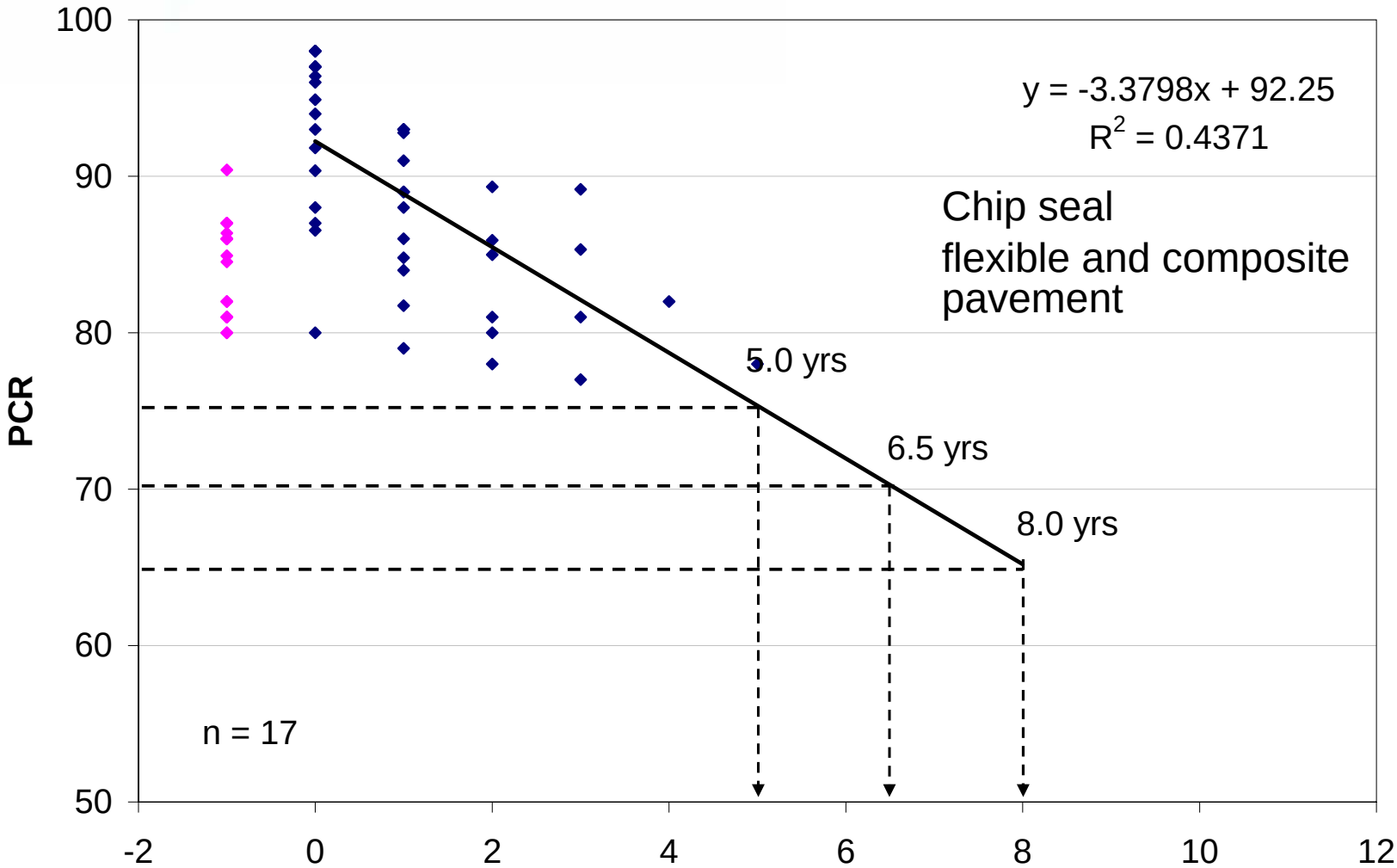


Tier 1 and Tier 2 Projects Combined – PCR Performance Model



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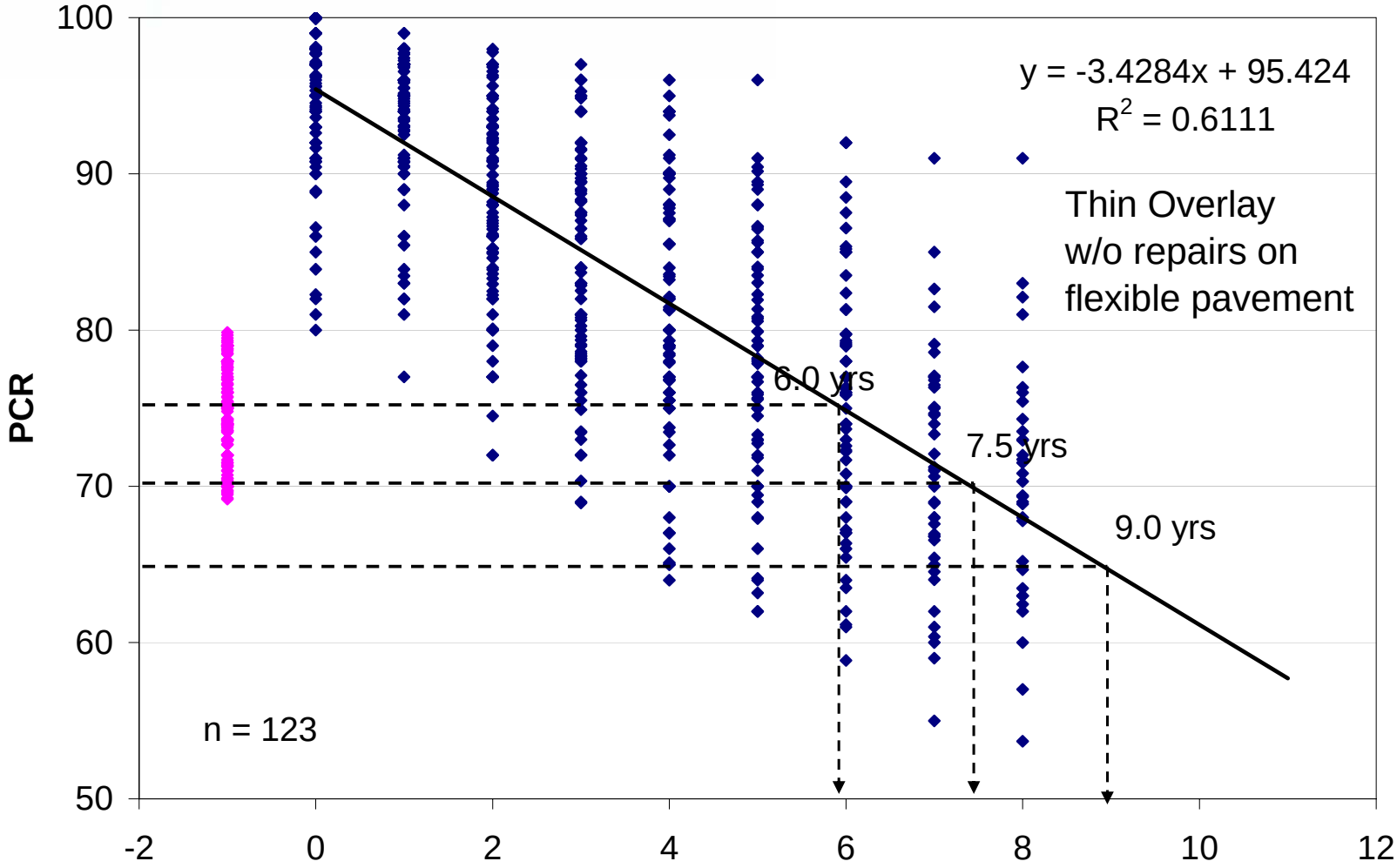

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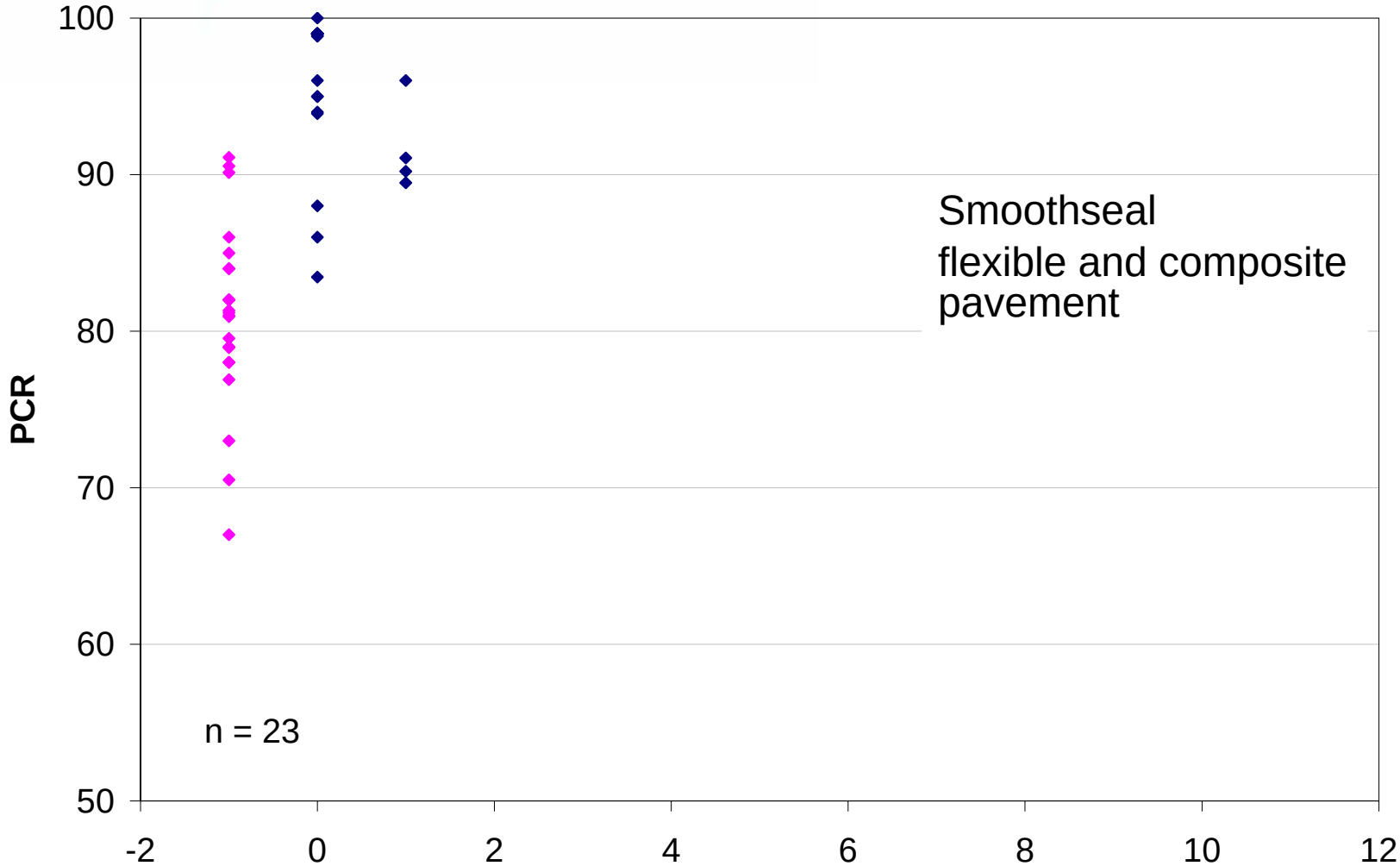
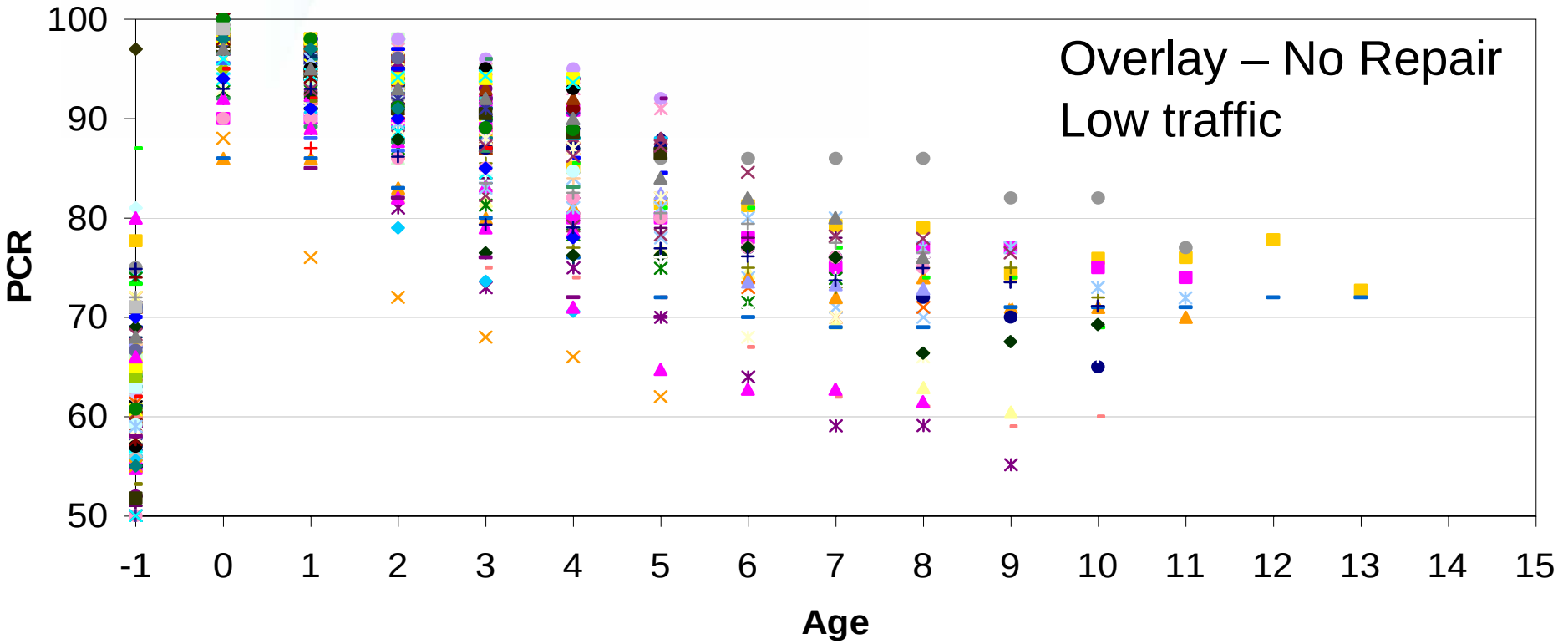


PM Treatment	Condition Prior to Treatment	Pavement Type	Regression Model	Number of projects, n	R^2	Treatment Age at Terminal PCR, Years		
						75	70	65
Chip seal	Fair	All	-2.0762 AGE + 89.954 *	17	0.32	7.0*		
	Good	All	-3.3798 AGE + 92.25	17	0.44	5.0	6.5	8.0
	All	All	-2.7 AGE + 91.107*	34	0.37	5.5*	7.5*	
Microsurfacing	Fair	All	-2.6482 AGE + 91.857*	19	0.28	6.5*	8.0*	
	Good	All	-0.436 AGE^2 -0.4833 AGE + 92.179	19	0.24	5.5	6.5	7.5
	All	All	-2.552 AGE + 92.438	38	0.28	7.0*	8.5*	
Double Microsurfacing	All	All	Insufficient long-term data	17				
NovaChip®	All	All	-2.9966 AGE + 96.766	9	0.46	7.5	9.0	
Smoothseal	All	All	Insufficient long-term data	23				
Thin Overlay without Repairs	Fair	Flexible	-3.4284 AGE + 95.424	123	0.61	6.0	7.5	9.0
	Good	Flexible	-2.8179 AGE + 95.365	102	0.53	7.0	9.0	10.5
	Fair	Composite	-3.1076 AGE + 92.817	75	0.49	5.5	7.5	9.0
	Good	Composite	-3.3702 AGE + 96.147	28	0.60	6.5	8.0	9.5
Thin Overlay with Repairs	Fair	Flexible	-2.4205 AGE + 96.012	26	0.41	8.5	10.5	
	Good	Flexible	-3.1411 AGE + 94.197*	12	0.53	6.0*	7.5*	9.0*
	Fair	Composite	-3.4486 AGE + 98.882	12	0.76	7.0	8.5	10.0
	Good	Composite	-2.6185 AGE + 98.927*	7	0.83	9.0*	11.0*	

Control Projects: PCR vs. Age



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9ADA348R 5COS079R 8PRE503R 9BRO505R 9BRO505R 5PER312R 5COS206R 1PUT189R 10HOC327R 10VIN327R
5GUE513R 10MRG078R 5PER669R 5LIC158R 9ADA137R 5COS206R 7CHP056R 10ATH550R 6UNI245R 5PER155R
3CRA103R 10MRG083R 9BRO505R 5GUE662R 5COS643R 8PRE503R 10ATH690R 5GUE541R 5PER668R 5COS060R
10NOB078R 3CRA103R 5MUS376R 9JAC124R 8PRE503R 8GRE343R 1WYA293R 8PRE725R 2SEN635R 3RIC598R
7CHP814R 3HUR598R 8CLI123R 3HUR060R 7CLA056R 8CLE749R 8CLI133R 10NOB078R 3CRA103R 10WAS550R
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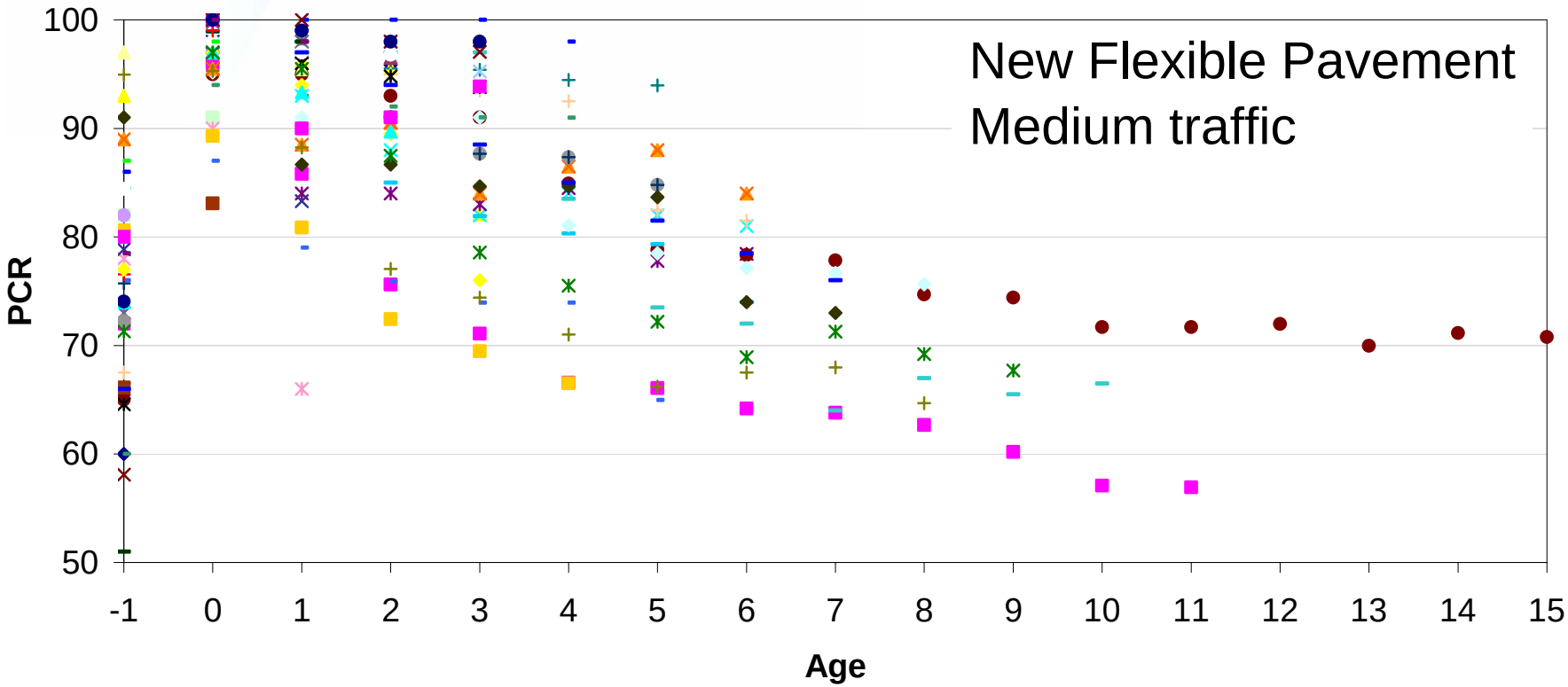
10WAS550R 5LIC146R

Control Projects: PCR vs. Age



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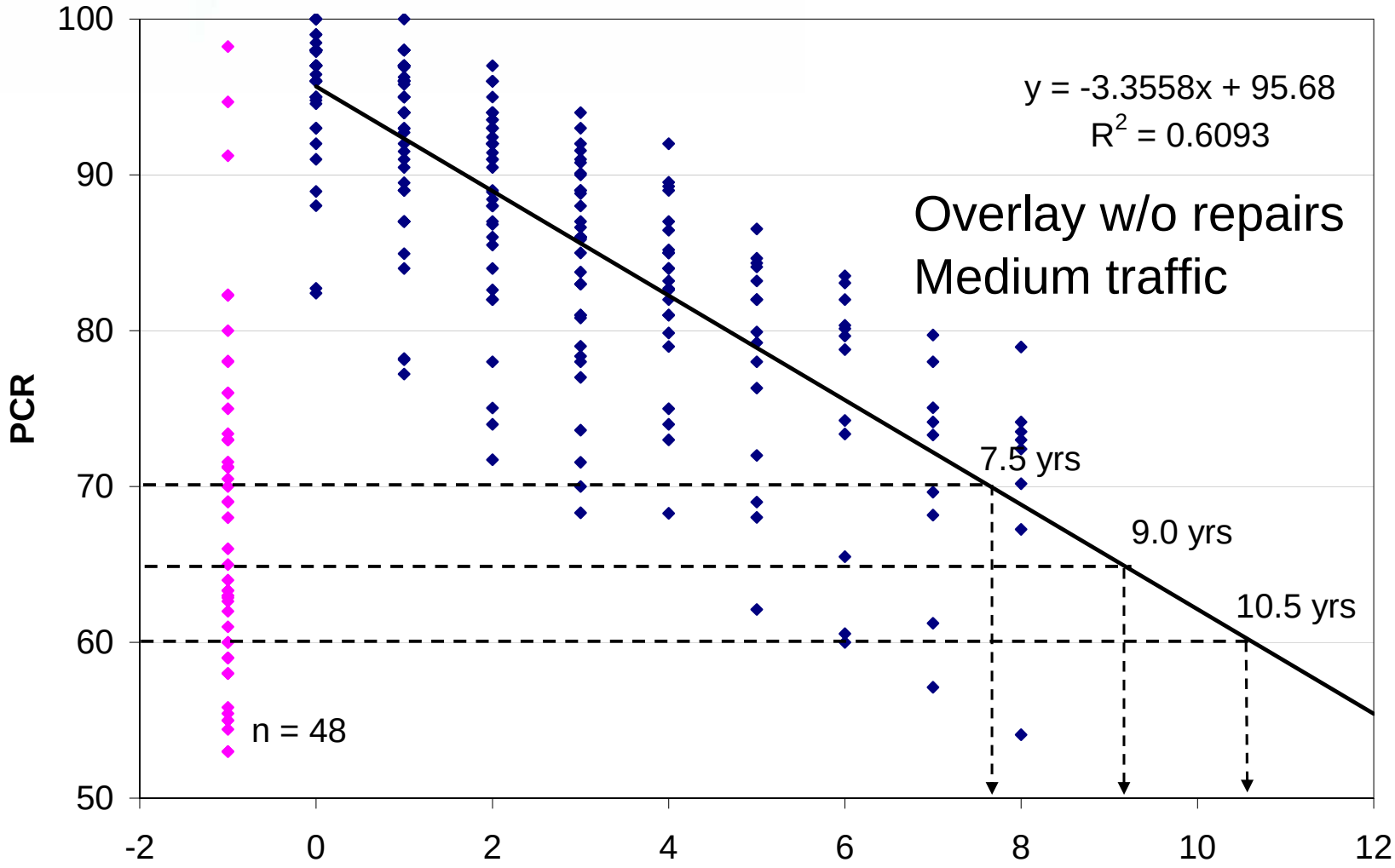
7LOG033R 4STA062R 7CHP068R 3ERI002R 4STA030R 3MED071R 4STA030R 3MED071R

Control Projects – PCR Model



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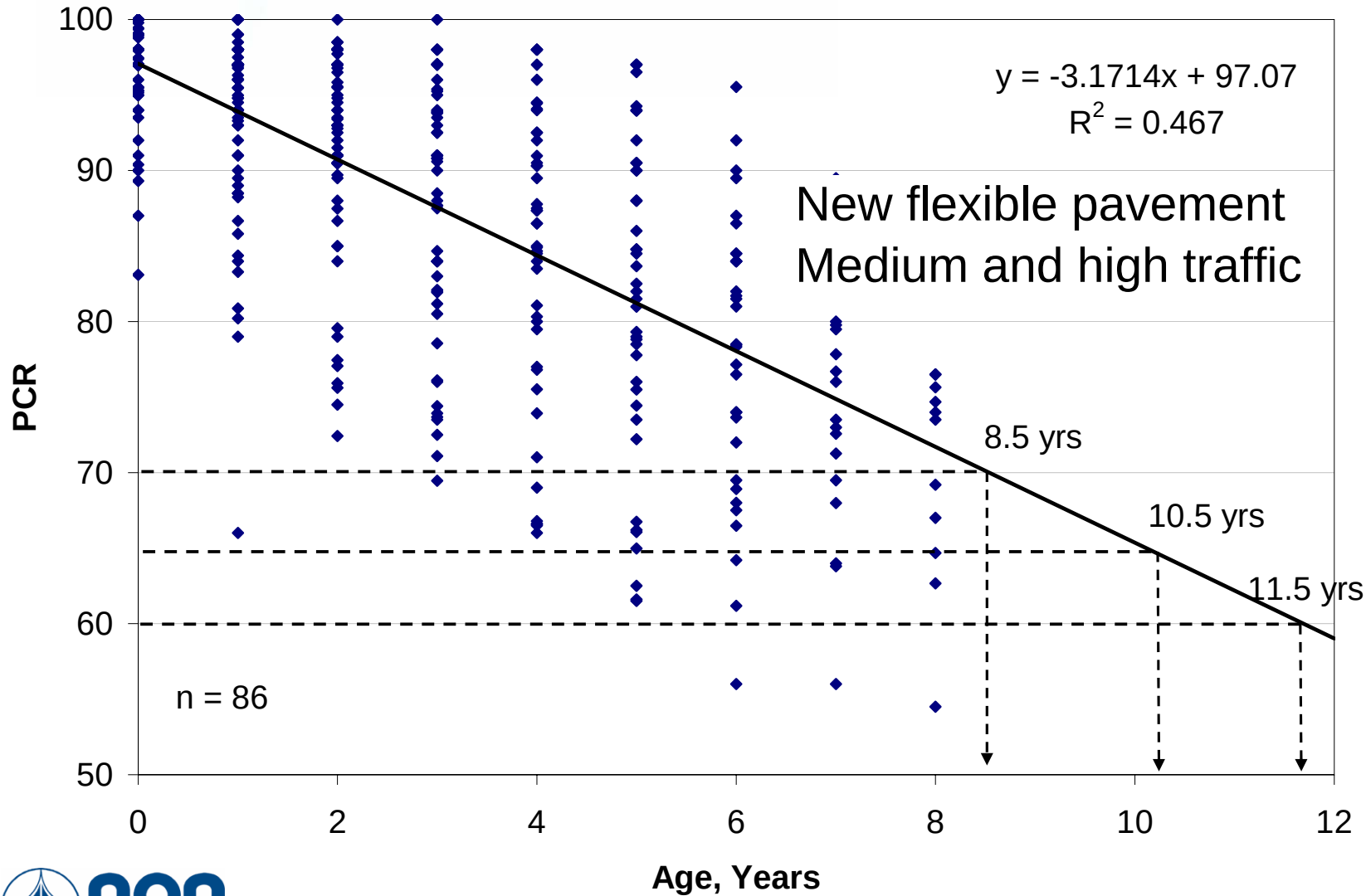


Type	Traffic	Priority Class	Regression Model	Number of projects, n	R^2	Age at Terminal PCR, Years		
						70	65	60
Overlay without repairs	Low	General	$0.0231\ AGE^2 - 3.5049\ AGE + 97.42$	102	0.69	8.5	10.0	11.5
		Urban	$-3.1942\ AGE + 96.384$	41	0.68	8.5	10.0	11.5
	Medium	Priority	$-2.6528\ AGE + 95.06$	105	0.48	9.5	11.5	
		General	$-3.3558\ AGE + 95.68$	48	0.61	7.5	9.0	10.5
		Urban	$0.046\ AGE^2 - 3.9254\ AGE + 96.297$	106	0.75	7.5	9.0	10.5
	High	Priority	$-3.0532\ AGE + 93.969$	196	0.49	8.0	9.5	11.0
Overlay with repairs	Low	General	$-1.3198\ AGE + 97.371$*	23	0.67	*		
		Urban	$-3.3442\ AGE + 96.076$	22	0.67	8.0	9.5	11.0
	Medium	Priority	$-2.4868\ AGE + 92.965$	25	0.56	9.5	11.5	
		Urban	$-2.9145\ AGE + 94.686$	39	0.52	8.5	10.5	12.0
	High	Priority	$0.0543\ AGE^2 - 4.1665\ AGE + 96.709$	93	0.59	7.0	8.5	10.5
New flexible pavement	Low Medium	General Urban	$-3.8854\ AGE + 98.107$	33	0.69	7.5	8.5	10.0
	Medium High	Priority	$-3.1714\ AGE + 97.07$	86	0.47	8.5	10.5	11.5

Tier 3 Projects

- 2005, 2006, 2007 Performance Data – PCR and Distress
- Statistical comparisons of control section versus test section for each year
- Case studies to validate performance models and cost-effectiveness analyses

PM Costs

- Official bid tabulation and plans for 10 PM projects awarded in FY ’05
- Cost summaries for PM projects awarded in FY ’03 and FY ’04
- ODOT website http://www.dot.state.oh.us/CONTRACT/estimating/

PM Costs

Included	Excluded
PM materials	Shoulder and bridge work (base course, prime coat, shoulder preparation, aggregate base)
Removal of reflective pavement markers (RPMs)	Wearing course removal and planing – bridges and intersections
Tack coat	Pavement repairs, joint and crack sealing
Traffic control items	Roadway items– rumble strips, drainage work, structure work, guardrail work, PCC work, etc.
Maintenance of traffic (MOT) items	Removal of drives, walks, curbs, signs, etc., and installation of curbs, signs, etc.
Incidental items	

Treatment and Conventional Overlay Costs

Chip seal: $1.13/sq. yd.
Microsurfacing: $2.40/sq. yd.
Double microsurfacing: $3.28/sq. yd.
Smoothseal (general system): $2.42/sq. yd.
Smoothseal (priority system): $2.94/sq. yd.
NovaChip: $3.86/sq. yd.
Thin HMAC overlay (general system): $3.68/sq. yd.
Thin HMAC overlay (priority system): $4.26/sq. yd.

Conventional HMAC overlay (general system): $6.97/sq. yd.
Conventional HMAC overlay (priority system w/ medium traffic): $8.47/sq. yd.
Conventional HMAC overlay (priority system w/ high traffic): $9.40/sq. yd.

Cost-Effectiveness

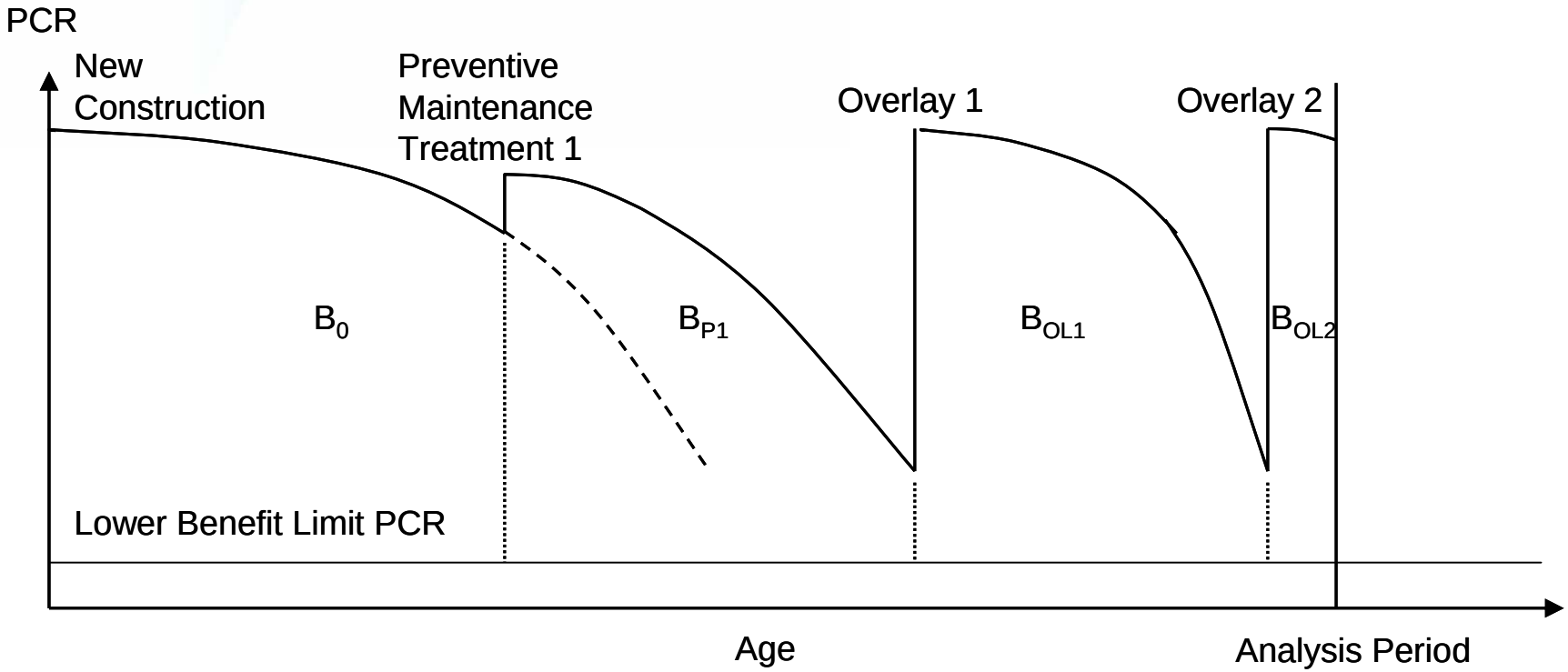
- **Life-Cycle Cost Analysis**

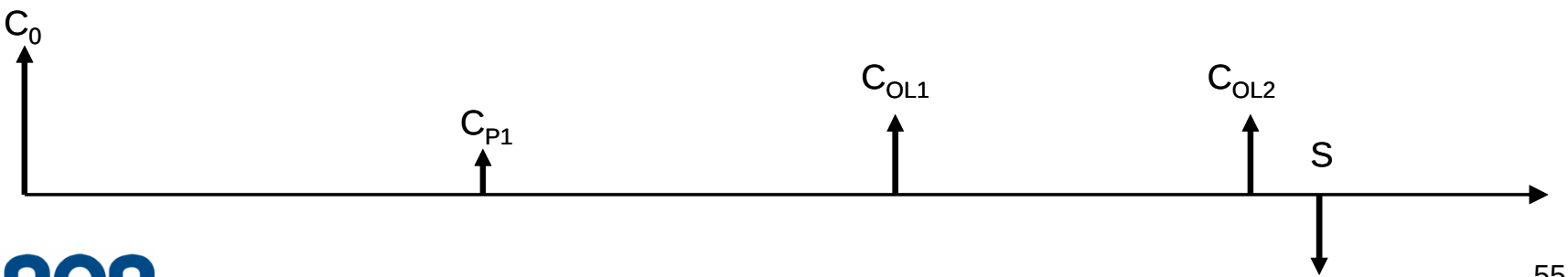
$$NPV = Initial\,Cost + \sum Future\,Cost * \left[\frac{1}{(1+i)^n}\right]$$

NPV = Net Present Value, $/sq. yd.
n = Time of future cost, years
i = Discount rate

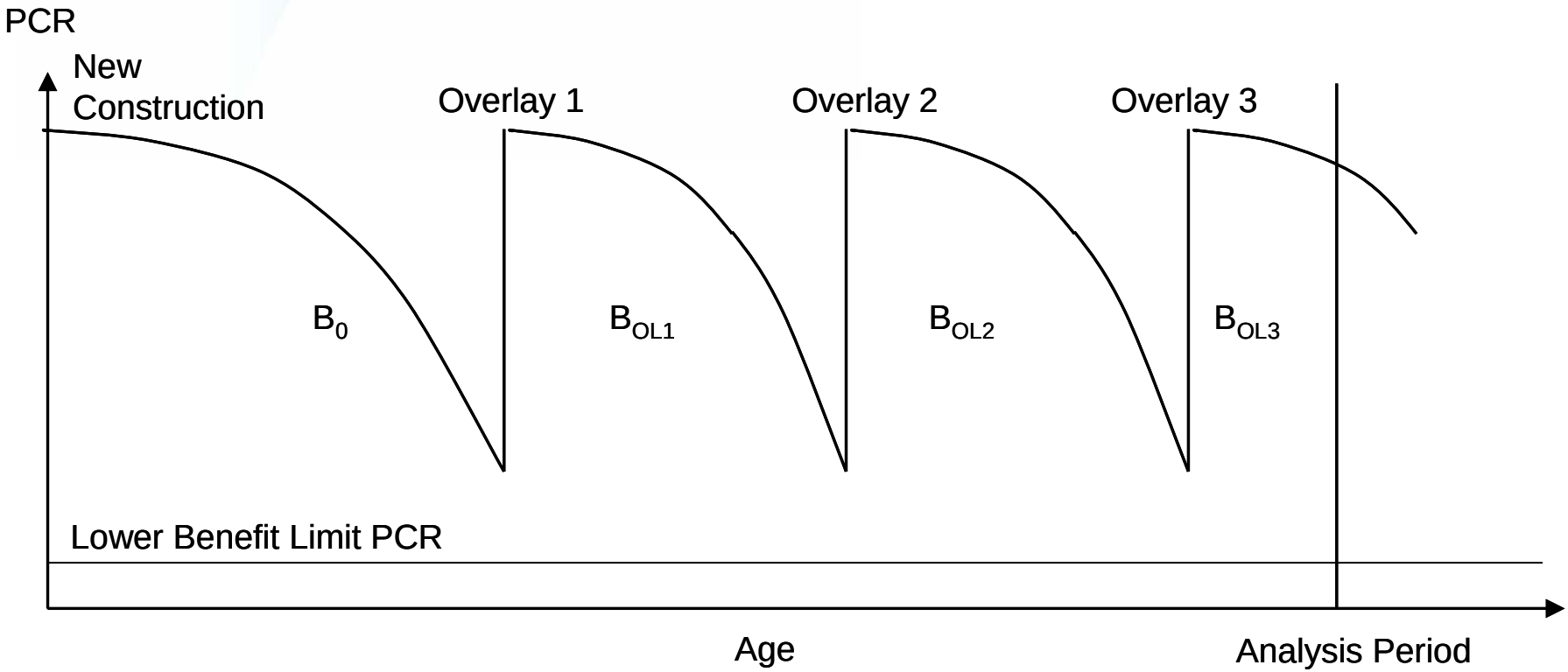
- **Benefit/Cost Ratio**
  - **Benefit = Area under Performance Curve (PCR vs. Age)**
  - **Cost = NPV**

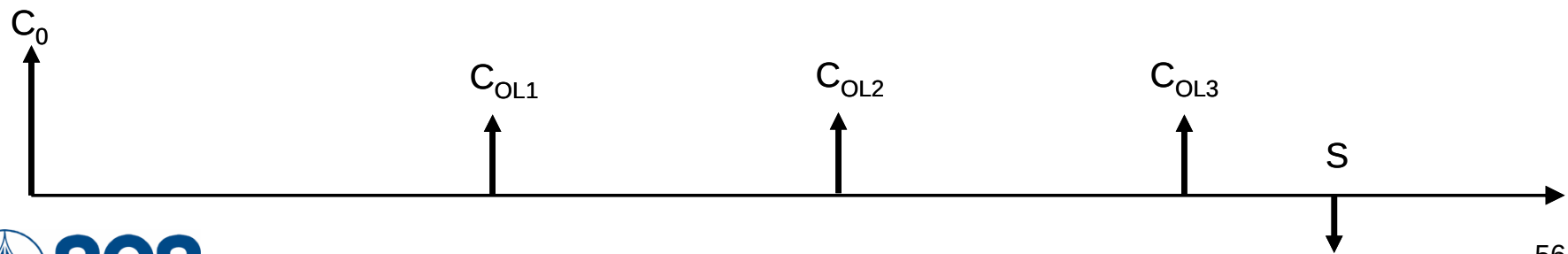
Benefits and Costs – 1 PM Treatment





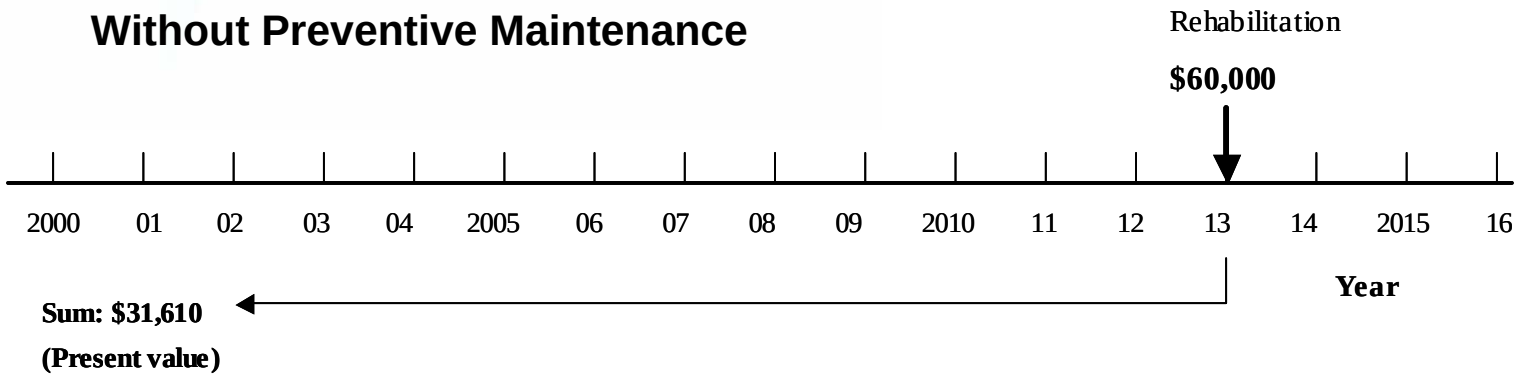
Benefits and Costs – No PM Treatment



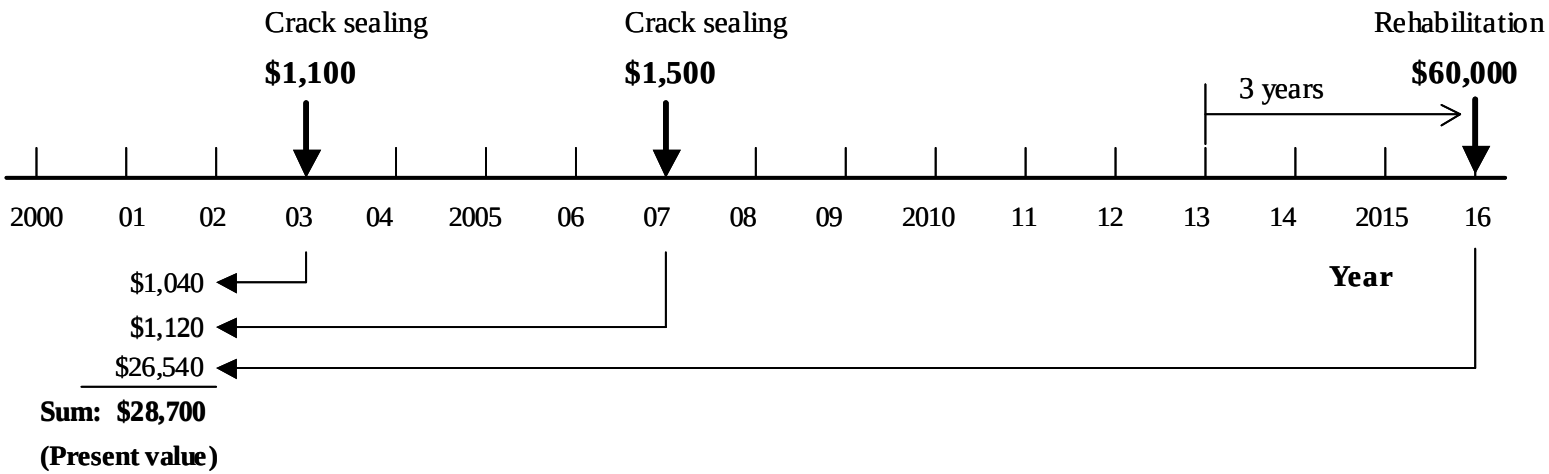


Cost-Effectiveness Example

Without Preventive Maintenance



With Preventive Maintenance



Cost-Effectiveness Analysis

- Lower Benefit Limit = 50
- Upper Benefit Limit = 100
- Analysis Period = 35 years
- PCR Prior to Treatment
  - Good Condition: 85
  - Fair Condition: 75
- PCR Prior to Overlay
  - General/Urban Pavement: 65
  - Priority Pavements: 70

Cost-Effectiveness Analysis

- 2nd and 3rd overlay performance same as that of the 1st overlay
- Flexible pavement performance same as that of composite pavement
- Composite pavement performance modeled as an overlay
- Analyses performed for 3 initial construction costs: $10, $15, and $20 per sq. yd.
- Discount rate from 0 percent to 6 percent

Treatment Type:	NovaChip
Condition:	Fair
Pavement Type:	Flexible
Priority Class:	Priority
Traffic Level:	High

	A	B	C
New Pavement Function:	0	-3.1714	97.07
Treatment Function:	0	-2.9966	96.766
Overlay Function:	0	-3.0532	93.969

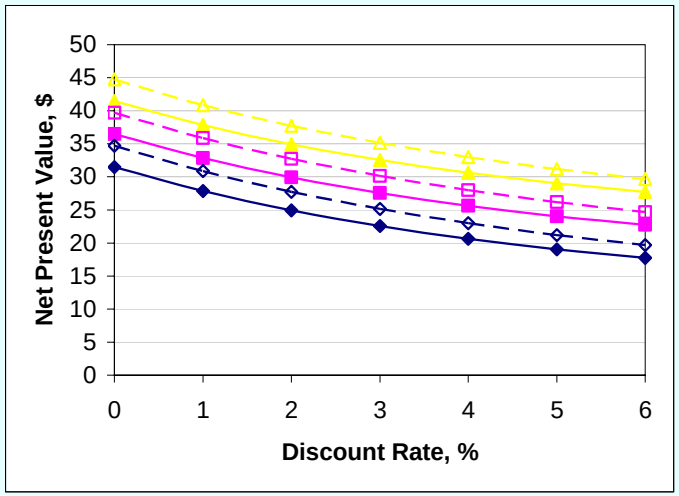
Form: $A x^2 + B x + C$

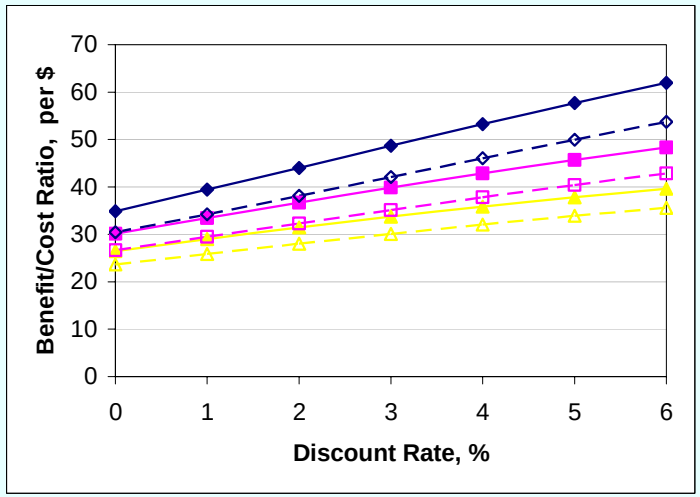
Treatment	
PCR Prior to Treatment:	75
Age at Treatment:	8.0
Treatment Life:	8.0
PCR Prior to Overlay:	70
Age at 1st Overlay:	17.0
1st Overlay Life:	9.5
Age at 2nd Overlay:	27.5
2nd Overlay Life:	9.5
Remaining Life:	2.0
Benefit:	1098

Control	
PCR Prior to Overlay:	70
Age at 1st Overlay:	9.5
1st Overlay Life:	9.5
Age at 2nd Overlay:	20.0
2nd Overlay Life:	9.5
Age at 3rd Overlay:	30.5
3rd Overlay Life:	9.5
Remaining Life:	5.0
Benefit:	1058

Costs		
Treatment:	$	3.86
1st Overlay:	$	9.40
2nd Overlay:	$	10.40
3rd Overlay:	$	10.40
Salvage Value:	$	2.19

Age Extension Due to Treatment:	7.5
Age Extension per Unit Cost:	1.9





Legend:

- Initial Cost: $10.00 Control section
- Initial Cost: $15.00 Control section
- Initial Cost: $20.00 Control section
- Initial Cost: $10.00 Treatment section
- Initial Cost: $15.00 Treatment section
- Initial Cost: $20.00 Treatment section

Results @ 4% Discount Rate and $15.00 Initial Construction Costs

	Treatment	Control	Better?
LCC Costs:	$ 25.63	$ 27.98	**Treatment**
Benefit/Costs:	42.86	37.80	**Treatment**

Treatment Type:	Microsurfacing
Condition:	Good
Pavement Type:	Flexible
Priority Class:	Priority
Traffic Level:	Medium

	A	B	C
New Pavement Function:	0	-3.1714	97.07
Treatment Function:	-0.436	-0.4833	92.179
Overlay Function:	0	-2.4868	92.965

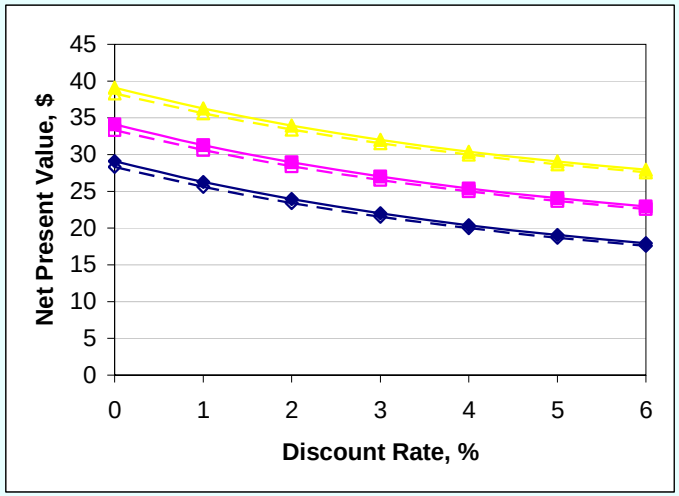
Form: $A x^2 + B x + C$

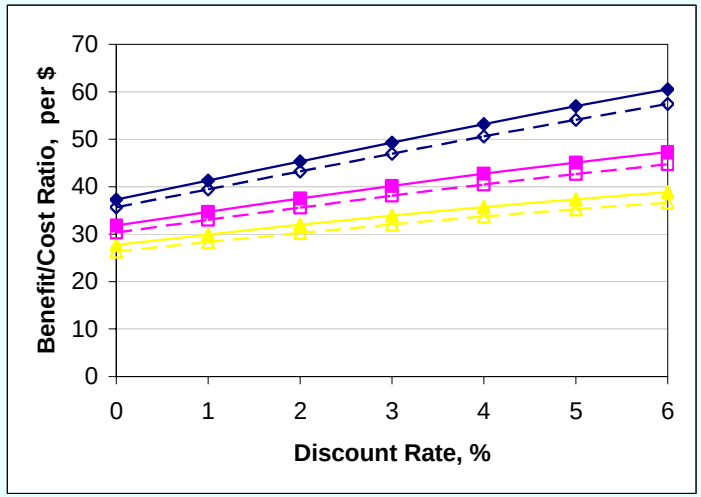
Treatment	
PCR Prior to Treatment:	85
Age at Treatment:	5.0
Treatment Life:	6.5
PCR Prior to Overlay:	70
Age at 1st Overlay:	12.5
1st Overlay Life:	11.5
Age at 2nd Overlay:	25.0
2nd Overlay Life:	11.5
Remaining Life:	1.5
Benefit:	1085

Control	
PCR Prior to Overlay:	70
Age at 1st Overlay:	9.5
1st Overlay Life:	11.5
Age at 2nd Overlay:	22.0
2nd Overlay Life:	11.5
Age at 3rd Overlay:	34.5
3rd Overlay Life:	11.5
Remaining Life:	11.0
Benefit:	1011

Costs		
Treatment:	$	2.40
1st Overlay:	$	8.47
2nd Overlay:	$	9.47
3rd Overlay:	$	9.47
Salvage Value:	$	1.24

Age Extension Due to Treatment:	3
Age Extension per Unit Cost:	1.3





Legend:

- Initial Cost: $10.00 Control section
- Initial Cost: $15.00 Control section
- Initial Cost: $20.00 Control section
- Initial Cost: $10.00 Treatment section
- Initial Cost: $15.00 Treatment section
- Initial Cost: $20.00 Treatment section

Results @ 4% Discount Rate and $15.00 Initial Construction Costs

	Treatment	Control	Better?
LCC Costs:	$ 25.40	$ 24.98	**Control**
Benefit/Costs:	42.73	40.46	**Treatment**

Preliminary Observations

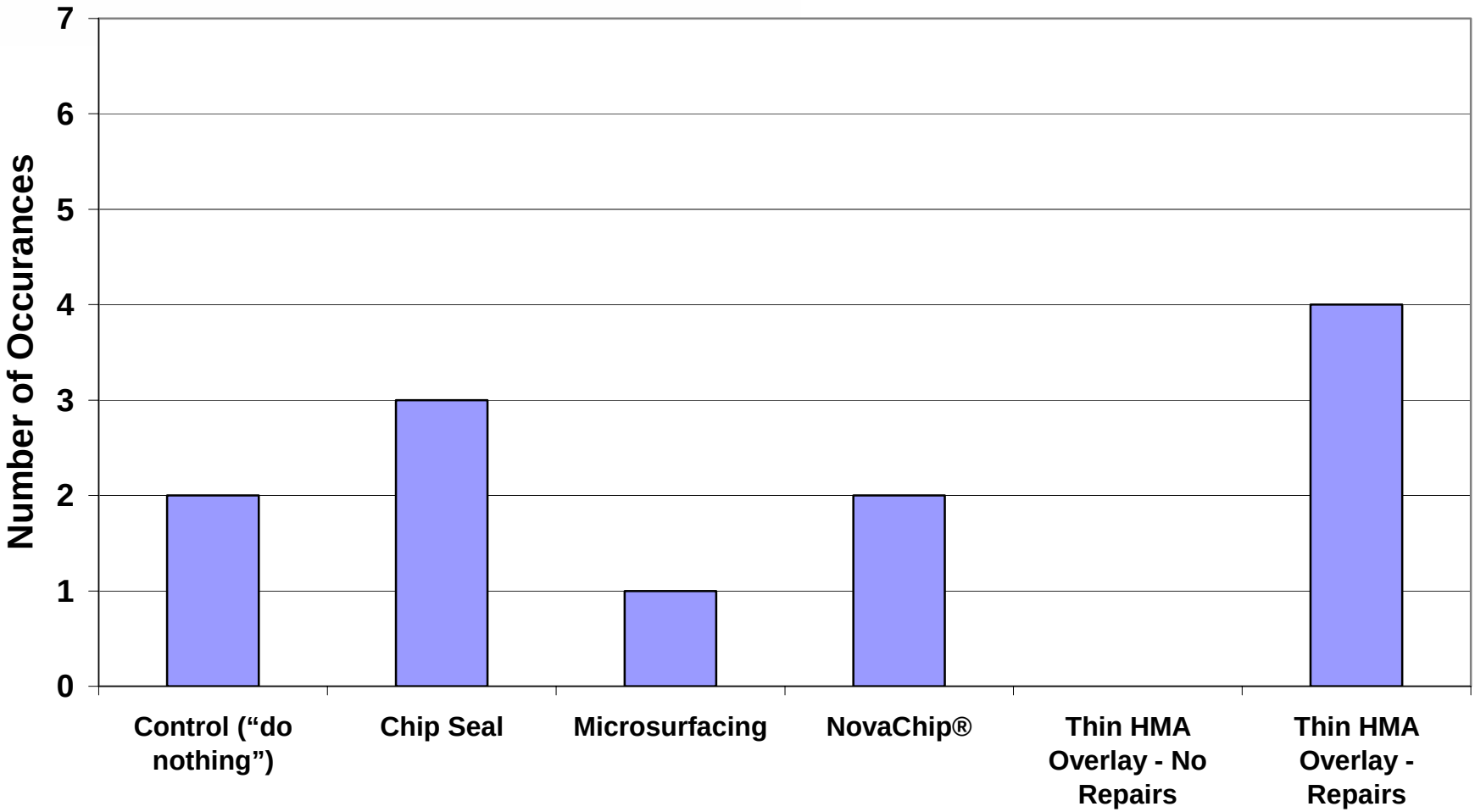
- The initial year analysis indicates that the majority of PM treatments have the potential to be cost-effective
- Current performance data limited in the 4 to 8 year range for the various PM treatments
- Additional performance data will become available in 2006/2007
- Value of Tier 3 projects expected to be somewhat limited due to young age and relatively short control sections

Preliminary Observations

- Smoothseal and double microsurfacing projects have a short history in the performance database
- In some cases, performance data was combined for several analysis cells, e.g. low and medium traffic and general and urban roadways
- The effectiveness of PM treatments is sensitive to both PM and overlay cost
- The risk associated with agency and contractor experience/lack of experience with new technologies is not captured in the analysis

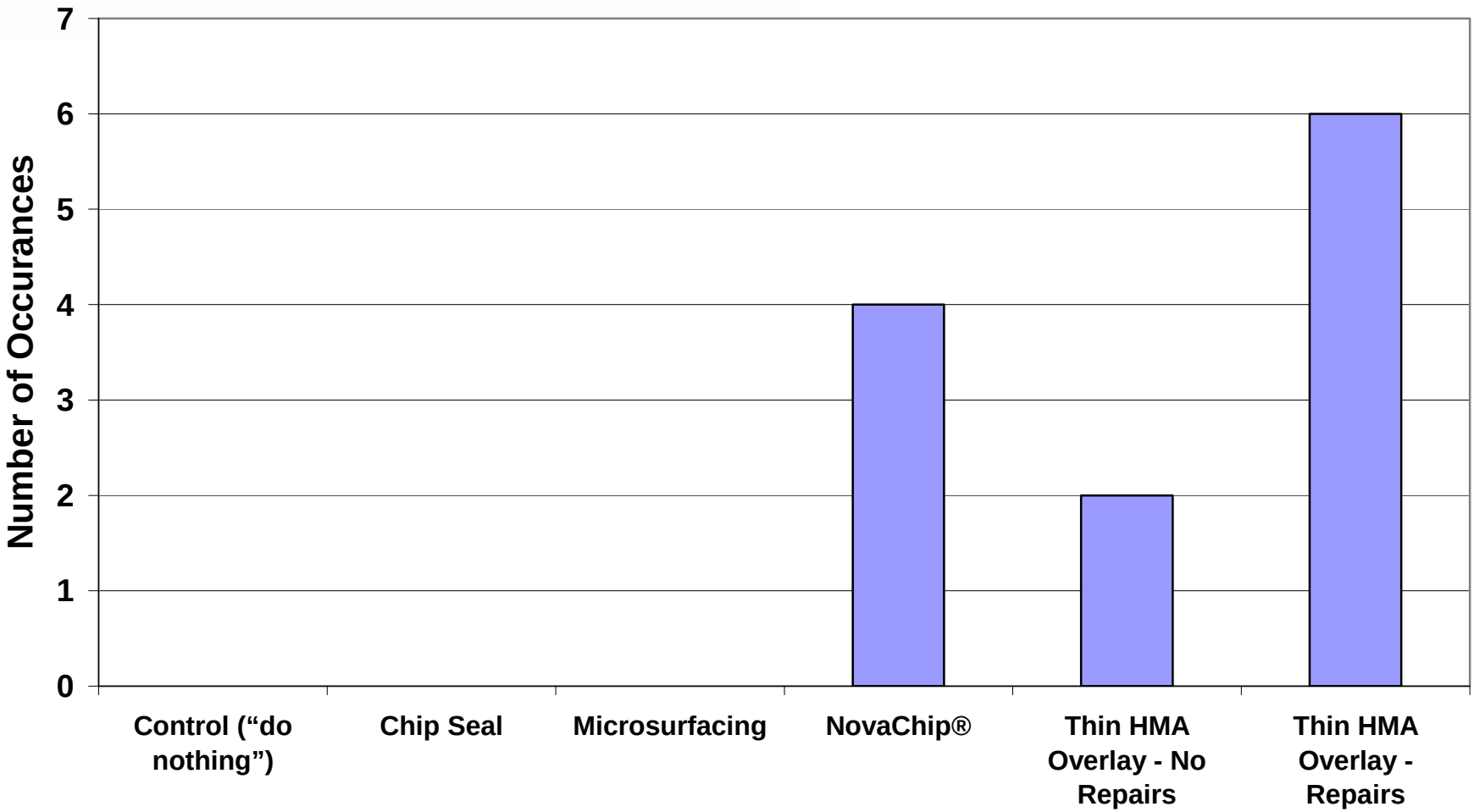
PM Alternative Comparison - LCCA

Occurances Where Alternative is Lowest Life-Cycle Cost



PM Alternative Comparison – B/C

Occurances Where Alternative is Highest Benefit/Cost



Future Activities

- Improved performance models
  - Additional PCR data
- Improved categorization
  - Expanded analysis cells
- Multiple overlay models
  - 2nd and 3rd overlay versus 1st overlay
- Overlay pavement type
  - Separate flexible versus composite
- Improved cost estimates
- More detailed evaluation of Tier 3 projects

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Questions?