ODOT Preventive Maintenance Process Analysis

David Hein, P.E.
Principal Engineer

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
Expanding the Realm of Possibility

Pavement Condition Vs Time

- Good
- Poor

Routine Maintenance

Preventive Maintenance

Rehabilitation

Reconstruction

Time (Years)
# Pavement Preservation

## Pavement Preservation Guidelines

<table>
<thead>
<tr>
<th>Pavement Preservation</th>
<th>Type of Activity</th>
<th>Increase Capacity</th>
<th>Increase Strength</th>
<th>Reduce Aging</th>
<th>Restore Serviceability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New Construction</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Reconstruction</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Major (Heavy) Rehabilitation</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structural Overlay</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Minor (Light) Rehabilitation</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Preventive Maintenance</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Routine Maintenance</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corrective (Reactive)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Catastrophic Maintenance</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
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

Power broom or sweeper  Rubber-tired rollers  Cover aggregate  Self-propelled aggregate spreader  Asphalt distributor

May be one unit
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

Expanding the Realm of Possibility
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

Smoothsealing SR82 in Cuyahoga County - 2003
Types of Smoothseal

[Image of two types of Smoothseal samples labeled Type A and Type B]
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

#### Pavement Surface/Type

- Asphalt
- Concrete
- Exposed PCC
- Surfaced-Treated
- Gravel-Surfaced

#### Other Features

- Drainage improvements
- Vegetation control
- Etc.

#### Trigger Values and Timing of Maintenance

**Distress type, severity and density**

- Roughness
- Rutting
- Alligator cracking
- Flushing, etc.

#### Available Treatments

- Hot and cold mix patching
- Spray patching (manual chip seal)
- Routing and sealing of cracks
- Micro-surfacing
- Etc.

#### Management Aspects

- Pavement/maintenance management system
- Other planning tools

#### Treatment Selection

#### Treatment Implementation

#### Technical Aspects

- Roadway functional type
- Geographical area/environment
- Size of municipality

---

Repeat for other pavement types and features
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

Pavement performance curve

Change due to a preventive maintenance treatment

Minimum recommended condition

Benefit

Extended pavement life due to preventive maintenance

Preventive Maintenance

Maintenance and Rehabilitation

Reconstruction

Pavement Condition Rating

Pavement Age, years
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

<table>
<thead>
<tr>
<th>Treatment Type</th>
<th>Number of Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack Seal</td>
<td>20</td>
</tr>
<tr>
<td>Chip Seal</td>
<td>25</td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>35</td>
</tr>
<tr>
<td>Double Microsurfacing</td>
<td>15</td>
</tr>
<tr>
<td>Novachip</td>
<td>5</td>
</tr>
<tr>
<td>Smoothseal</td>
<td>20</td>
</tr>
<tr>
<td>Thin HMAC with no repairs</td>
<td>10</td>
</tr>
<tr>
<td>Thin HMAC with repairs</td>
<td>5</td>
</tr>
</tbody>
</table>

Expanding the Realm of Possibility

ARA
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

Expanding the Realm of Possibility
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


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

Pavement Condition

Minimum acceptable service level

Past performance

Predicted performance

Remaining service life

Pavement Age, years

Now

Now +2

Now +5
Tier 1 Projects: PCR vs. Age

Chip Seal
General
Flexible
Tier 1 Projects: PCR vs. Age

Microsurfacing
Urban
Flexible

PCR vs. Year

8GRE042R, 85,000 ESALs/yr - Warranty
2OTT163R, 122,000 ESALs/yr - Warranty
4STA093R, 143,000 ESALs/yr - Nonwarranty
8WAR048R, 146,000 ESALs/yr - Nonwarranty
2OTT163R, 149,000 ESALs/yr - Warranty
2WO0023R, 1128,000 ESALs/yr - Warranty
Tier 1 Projects: PCR vs. Age

Smoothseal
Urban
Flexible

- 8BUT177R, 29,000 ESALs/yr - Nonwarranty
- 3RIC430R, 39,000 ESALs/yr - Nonwarranty
- 11TUS039R, 195,000 ESALs/yr - Warranty
- 8HAM127R, 226,000 ESALs/yr - Nonwarranty
- 5PER345R, 61,000 ESALs/yr - Warranty
Tier 1 and Tier 2 Projects Combined – PCR Performance Model

\[
y = -3.3798x + 92.25 \\
R^2 = 0.4371
\]

Chip seal flexible and composite pavement

PCR

Age, Years

n = 17
Tier 1 and Tier 2 Projects Combined – PCR Performance Model

\[ y = -3.4284x + 95.424 \]

\[ R^2 = 0.6111 \]

Thin Overlay w/o repairs on flexible pavement

- 6.0 yrs
- 7.5 yrs
- 9.0 yrs

n = 123
Tier 1 and Tier 2 Projects Combined – PCR Performance Model

![Graph showing PCR performance model with data points for Smoothseal flexible and composite pavement. The graph includes a label indicating there are 23 observations (n = 23).]
<table>
<thead>
<tr>
<th>PM Treatment</th>
<th>Condition Prior to Treatment</th>
<th>Pavement Type</th>
<th>Regression Model</th>
<th>Number of projects, n</th>
<th>R²</th>
<th>Treatment Age at Terminal PCR, Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>Chip seal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70*</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>All</td>
<td>-2.0762 AGE + 89.954 *</td>
<td>17</td>
<td>0.32</td>
<td>7.0*</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>All</td>
<td>-3.3798 AGE + 92.25</td>
<td>17</td>
<td>0.44</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>All</td>
<td>-2.7 AGE + 91.107*</td>
<td>34</td>
<td>0.37</td>
<td>5.5*</td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>Fair</td>
<td>All</td>
<td>-2.6482 AGE + 91.857*</td>
<td>19</td>
<td>0.28</td>
<td>6.5*</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>All</td>
<td>-0.436 AGE&lt;sup&gt;2&lt;/sup&gt; -0.4833 AGE + 92.179</td>
<td>19</td>
<td>0.24</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>All</td>
<td>-2.552 AGE + 92.438</td>
<td>38</td>
<td>0.28</td>
<td>7.0*</td>
</tr>
<tr>
<td>Double Microsurfacing</td>
<td>All</td>
<td>All</td>
<td>Insufficient long-term data</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NovaChip&lt;sup&gt;®&lt;/sup&gt;</td>
<td>All</td>
<td>All</td>
<td>-2.9966 AGE + 96.766</td>
<td>9</td>
<td>0.46</td>
<td>7.5</td>
</tr>
<tr>
<td>Smoothseal</td>
<td>All</td>
<td>All</td>
<td>Insufficient long-term data</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thin Overlay without Repairs</td>
<td>Fair</td>
<td>Flexible</td>
<td>-3.4284 AGE + 95.424</td>
<td>123</td>
<td>0.61</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>Flexible</td>
<td>-2.8179 AGE + 95.365</td>
<td>102</td>
<td>0.53</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>Composite</td>
<td>-3.1076 AGE + 92.817</td>
<td>75</td>
<td>0.49</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>Composite</td>
<td>-3.3702 AGE + 96.147</td>
<td>28</td>
<td>0.60</td>
<td>6.5</td>
</tr>
<tr>
<td>Thin Overlay with Repairs</td>
<td>Fair</td>
<td>Flexible</td>
<td>-2.4205 AGE + 96.012</td>
<td>26</td>
<td>0.41</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>Flexible</td>
<td>-3.1411 AGE + 94.197*</td>
<td>12</td>
<td>0.53</td>
<td>6.0*</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
<td>Composite</td>
<td>-3.4486 AGE + 98.882</td>
<td>12</td>
<td>0.76</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>Composite</td>
<td>-2.6185 AGE + 98.927*</td>
<td>7</td>
<td>0.83</td>
<td>9.0*</td>
</tr>
</tbody>
</table>
Control Projects: PCR vs. Age

Overlay – No Repair
Low traffic
Control Projects: PCR vs. Age

New Flexible Pavement
Medium traffic

Expanding the Realm of Possibility
Control Projects – PCR Model

Overlay w/o repairs
Medium traffic

\[ y = -3.3558x + 95.68 \]
\[ R^2 = 0.6093 \]

\[ n = 48 \]
Control Projects – PCR Model

\[
y = -3.1714x + 97.07 \\
R^2 = 0.467
\]

New flexible pavement
Medium and high traffic

PCR

Age, Years

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

* Denotes linear regression model.
Tier 3 Projects

- 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

<table>
<thead>
<tr>
<th>Included</th>
<th>Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM materials</td>
<td>Shoulder and bridge work (base course, prime coat, shoulder preparation, aggregate base)</td>
</tr>
<tr>
<td>Removal of reflective pavement markers (RPMs)</td>
<td>Wearing course removal and planing – bridges and intersections</td>
</tr>
<tr>
<td>Tack coat</td>
<td>Pavement repairs, joint and crack sealing</td>
</tr>
<tr>
<td>Traffic control items</td>
<td>Roadway items– rumble strips, drainage work, structure work, guardrail work, PCC work, etc.</td>
</tr>
<tr>
<td>Maintenance of traffic (MOT) items</td>
<td>Removal of drives, walks, curbs, signs, etc., and installation of curbs, signs, etc.</td>
</tr>
<tr>
<td>Incidental items</td>
<td></td>
</tr>
</tbody>
</table>
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**
  \[
  \text{NPV} = \text{Initial Cost} + \sum \text{Future Cost} \times \left[ \frac{1}{(1 + i)^n} \right]
  \]
  
  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

PCR

New Construction
Preventive Maintenance Treatment 1
Overlay 1
Overlay 2
Analysis Period

Age

Lower Benefit Limit PCR

B₀
Bₚ₁
B₀₁
B₀₂

C₀
Cₚ₁
C₀₁
C₀₂
S
Benefits and Costs – No PM Treatment

PCR

New Construction

Overlay 1

Overlay 2

Overlay 3

Lower Benefit Limit PCR

Age

Analysis Period

B_0

B_{OL1}

B_{OL2}

B_{OL3}

C_0

C_{OL1}

C_{OL2}

C_{OL3}

S

ARA

Expanding the Realm of Possibility
Cost-Effectiveness Example

Without Preventive Maintenance

Year

2000 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16

Rehabilitation
$60,000

Sum: $31,610
(Present value)

With Preventive Maintenance

Year

2000 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16

Rehabilitation
$60,000

Crack sealing
$1,100

Crack sealing
$1,500

3 years

Sum: $28,700
(Present value)

$1,040

$1,120

$26,540
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

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

#### New Pavement Function:

<table>
<thead>
<tr>
<th>Form: $A x^2 + B x + C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

#### Treatment Function:

<table>
<thead>
<tr>
<th>Form: $A x^2 + B x + C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

#### Overlay Function:

<table>
<thead>
<tr>
<th>Form: $A x^2 + B x + C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

### 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

<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
<th>1st Overlay</th>
<th>2nd Overlay</th>
<th>3rd Overlay</th>
<th>Salvage Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment</strong></td>
<td>$3.86</td>
<td>$9.40</td>
<td>$10.40</td>
<td>$10.40</td>
<td>$2.19</td>
</tr>
<tr>
<td><strong>1st Overlay</strong></td>
<td>$9.40</td>
<td>$10.40</td>
<td>$10.40</td>
<td>$2.19</td>
<td></td>
</tr>
<tr>
<td><strong>2nd Overlay</strong></td>
<td>$10.40</td>
<td>$10.40</td>
<td>$2.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3rd Overlay</strong></td>
<td>$10.40</td>
<td>$2.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Salvage Value</strong></td>
<td>$2.19</td>
<td>$2.19</td>
<td>$2.19</td>
<td>$2.19</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>LCC Costs:</th>
<th>Treatment</th>
<th>Control</th>
<th>Better?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit/Costs:</td>
<td>$42.86</td>
<td>$37.80</td>
<td>Treatment</td>
</tr>
</tbody>
</table>
Treatment Type: Microsurfacing
Condition: Good
Pavement Type: Flexible
Priority Class: Priority
Traffic Level: Medium

Expanding the Realm of Possibility

*New Pavement Function:*
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-3.1714</td>
<td>97.07</td>
</tr>
</tbody>
</table>

*Treatment Function:*
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.436</td>
<td>-0.4833</td>
<td>92.179</td>
</tr>
</tbody>
</table>

*Overlay Function:
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-2.4868</td>
<td>92.965</td>
</tr>
</tbody>
</table>

*Form:*
\[ A x^2 + B x + C \]

**Treatment**

<table>
<thead>
<tr>
<th>PCR Prior to Treatment:</th>
<th>85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at Treatment:</td>
<td>5.0</td>
</tr>
<tr>
<td>Treatment Life:</td>
<td>6.5</td>
</tr>
<tr>
<td>PCR Prior to Overlay:</td>
<td>70</td>
</tr>
<tr>
<td>Age at 1st Overlay:</td>
<td>12.5</td>
</tr>
<tr>
<td>1st Overlay Life:</td>
<td>11.5</td>
</tr>
<tr>
<td>Age at 2nd Overlay:</td>
<td>25.0</td>
</tr>
<tr>
<td>2nd Overlay Life:</td>
<td>11.5</td>
</tr>
<tr>
<td>Age at 3rd Overlay:</td>
<td>34.5</td>
</tr>
<tr>
<td>3rd Overlay Life:</td>
<td>11.5</td>
</tr>
<tr>
<td>Remaining Life:</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Control**

<table>
<thead>
<tr>
<th>PCR Prior to Overlay:</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at 1st Overlay:</td>
<td>9.5</td>
</tr>
<tr>
<td>1st Overlay Life:</td>
<td>11.5</td>
</tr>
<tr>
<td>Age at 2nd Overlay:</td>
<td>22.0</td>
</tr>
<tr>
<td>2nd Overlay Life:</td>
<td>11.5</td>
</tr>
<tr>
<td>Age at 3rd Overlay:</td>
<td>34.5</td>
</tr>
<tr>
<td>3rd Overlay Life:</td>
<td>11.5</td>
</tr>
<tr>
<td>Remaining Life:</td>
<td>11.5</td>
</tr>
</tbody>
</table>

**Costs**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>$2.40</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Overlay</td>
<td>$8.47</td>
</tr>
<tr>
<td>2nd Overlay</td>
<td>$9.47</td>
</tr>
<tr>
<td>3rd Overlay</td>
<td>$9.47</td>
</tr>
<tr>
<td>Salvage Value</td>
<td>$1.24</td>
</tr>
</tbody>
</table>

**Benefit:**

- Treatment: 1085
- Control: 1011

**Age Extension Due to Treatment:**

- Age Extension per Unit Cost: 3

**Legend:**

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

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

<table>
<thead>
<tr>
<th>LCC Costs: Benefit/Costs:</th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>$25.40</td>
<td>$24.98</td>
<td></td>
</tr>
<tr>
<td>$42.73</td>
<td>$40.46</td>
<td></td>
</tr>
</tbody>
</table>

Control
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

- Control (“do nothing”)
- Chip Seal
- Microsurfacing
- NovaChip®
- Thin HMA Overlay - No Repairs
- Thin HMA Overlay - Repairs

Number of Occurances

Expanding the Realm of Possibility
PM Alternative Comparison – B/C

Occurances Where Alternative is Highest Benefit/Cost

<table>
<thead>
<tr>
<th>Treatment Type</th>
<th>Number of Occurances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (&quot;do nothing&quot;)</td>
<td>0</td>
</tr>
<tr>
<td>Chip Seal</td>
<td>1</td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>2</td>
</tr>
<tr>
<td>NovaChip®</td>
<td>4</td>
</tr>
<tr>
<td>Thin HMA Overlay - No Repairs</td>
<td>2</td>
</tr>
<tr>
<td>Thin HMA Overlay - Repairs</td>
<td>6</td>
</tr>
</tbody>
</table>
Future Activities

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