Cost Effectiveness of the Michigan DOT and National Park Service (NPS) Preservation Programs

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Applied Pavement Technology, Inc.
Presentation Overview

• Cost-Effectiveness of the Michigan DOT Capital Preventive Maintenance (CPM) Program
  – Study objectives and research approach
  – Activities and findings
  – Conclusions

• Performance and Benefits of Surface Treatments on NPS Pavements
  – Study objectives and research approach
  – Activities and findings
  – Conclusions

• Lessons Learned
• Questions
Cost Effectiveness of the Michigan DOT CPM Program

- Sponsor: Michigan DOT
- Contractor: Applied Pavement Technology, Inc. (subcontractor Michigan Tech University)
- Time Period: October 2010 – March 2013
- Background
Study Objectives

• Determine the costs and benefits of pavement preservation options used by MDOT
• Document the costs and benefits of the MDOT pavement preservation program
• Determine the variability in the costs and benefits of each pavement preservation option
• Establish a relational matrix for the selection of time, location, and preservation option
Research Approach

- Data collection and data assembly
- Analyze historical pavement data and develop analysis categories
- Identify gaps/issues with data
- Develop pre- and post-CPM treatment performance models
- Conduct benefit-cost analysis of treatments and MDOT CPM program
- Develop matrix for selection of time, location, and treatment option
- Summarize study findings and recommendations
Data Collection and Assembly

- R&R and CPM projects ⇒ 3,300+ analysis segments
- Pavement type, CPM treatment(s), functional class, traffic level
- Historical Distress Index (DI) data (pre- & post-treatment)
- Climatic zones based on MDOT regions

MI Hardiness Zones

Zone 1
Zone 2
## CPM Treatments

<table>
<thead>
<tr>
<th>CPM Treatment</th>
<th>Number of Projects/Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Chip Seal</td>
<td>233</td>
</tr>
<tr>
<td>Double Chip Seal</td>
<td>87</td>
</tr>
<tr>
<td>HMA Crack Seal/Treatment</td>
<td>1,109</td>
</tr>
<tr>
<td>HMA Mill and Overlay</td>
<td>743</td>
</tr>
<tr>
<td>HMA Overlay</td>
<td>263</td>
</tr>
<tr>
<td>Ultra-Thin HMA Overlay</td>
<td>72</td>
</tr>
<tr>
<td>Double Microsurfacing</td>
<td>541</td>
</tr>
<tr>
<td>Paver Placed Surface Seal</td>
<td>38</td>
</tr>
<tr>
<td>PCC Joint and Crack Seal</td>
<td>72</td>
</tr>
<tr>
<td>Concrete Pavement Restoration (CPR)</td>
<td>331</td>
</tr>
</tbody>
</table>
Pavement Performance Modeling

DATA SET 1
Pre-CPM Treatment Performance Curve

DATA SET 2
Post-1st CPM Treatment Performance Curve

DATA SET 3
Post-2nd CPM Treatment Performance Curve

R&R Event (original pavement)

1st CPM Treatment

2nd CPM Treatment

Pavement Age (Years)

Distress Index

0 20 40 60 80

80 60 40 20 0
# Pre-CPM Treatment Data

![Bar chart showing number of analysis segments for different types of roads in Zone 1 and Zone 2.](chart)

- **Zone 2**
  - **Collectors**
    - Flexible: 26
    - Composite: 51
    - Rigid: 0
  - **Minor Arterials**
    - Flexible: 3
    - Composite: 85
    - Rigid: 38
  - **Principal Arterials**
    - Flexible: 46
    - Composite: 379
    - Rigid: 518
  - **Interstates, Other Freeways**
    - Flexible: 12
    - Composite: 187
    - Rigid: 333

- **Zone 1**
  - **Collectors**
    - Flexible: 0
    - Composite: 187
    - Rigid: 287
  - **Minor Arterials**
    - Flexible: 1
    - Composite: 76
    - Rigid: 31
  - **Principal Arterials**
    - Flexible: 2
    - Composite: 314
    - Rigid: 287
  - **Interstates, Other Freeways**
    - Flexible: 1
    - Composite: 182
    - Rigid: 26

**Totals**
- Flexible Total: 1,105
- Composite Total: 1,992
- Rigid Total: 230
- TOTAL: 3,327
Performance Modeling

• Multiple regression models to identify significant factors
  – Dependent variable: DI
  – Independent variables: climatic zone (1 and 2), pavement type (flexible, composite, rigid), pavement age (years since last R&R), functional class, traffic, pre-treatment DI

• Data filtering techniques

• Functional class ➞ poor models

• Traffic, pre-treatment DI ➞ not significant factors in many cases

• Focus on “DI vs age”
Treatment Performance and Benefit Analysis

Percent Benefit Area = \( \frac{\text{Post-Treatment Area}}{\text{Pre-Treatment Area}} \)

Benefit-Cost Ratio = \( \frac{\text{Percent Benefit Area}}{\text{Unit Cost of Treatment}} \)

Threshold DI Value: 40

Pre-Treatment Area

Post-Treatment Area

Service Life Extension
# Treatment Performance and Cost Benefit

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Average Pavement Life Extension (Years)</th>
<th>Percent Benefit over Pre-Treatment Performance</th>
<th>Average Unit Cost (per yd²)</th>
<th>Benefit-Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flexible Pavements</td>
<td>Composite Pavements</td>
<td>Flexible Pavements</td>
<td>Composite Pavements</td>
</tr>
<tr>
<td>HMA Overlay (non-structural)</td>
<td>3.6 to 4.0</td>
<td>2.2 to 4.2</td>
<td>35 to 49</td>
<td>12 to 21</td>
</tr>
<tr>
<td>HMA Mill and Overlay (non-structural)</td>
<td>7.8 to 7.9</td>
<td>3.6 to 8.5</td>
<td>49 to 79</td>
<td>26 to 68</td>
</tr>
<tr>
<td>Ultra-Thin HMA Overlay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Chip Seal</td>
<td>2.7 to 6.6</td>
<td></td>
<td>15 to 63</td>
<td></td>
</tr>
<tr>
<td>Double Chip Seal</td>
<td>6.9</td>
<td>1.9</td>
<td>40</td>
<td>32</td>
</tr>
<tr>
<td>Double Micro-surfacing</td>
<td>1.8 to 7.8</td>
<td>9.8 to 11.6</td>
<td>22 to 61</td>
<td>49 to 56</td>
</tr>
<tr>
<td>Paver Placed Surface Seal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HMA Crack Seal/Treatment</td>
<td>0.6 to 2.8</td>
<td>0.9 to 2.1</td>
<td>4 to 12</td>
<td>5 to 21</td>
</tr>
</tbody>
</table>
Flexible Pavement Models

Pavement Age (Years)

Distress Index

Pre-Treatment
First CPM Treatments
Post-first CPM Treatments

19 yrs
27 yrs
34 yrs
Composite Pavement Models

Pavement Age (Years)

Distress Index

Pre-Treatment  First CPM Treatments  Post-first CPM Treatments

20 yrs  28 yrs  36 yrs
Study Conclusions

• Flexible and composite pavement CPM treatments effective
  – Service life extensions and benefits vary by treatment, pavement type, and climate
  – Sequential CPM treatments (1st and 2nd combined) provide life extensions of 15-16 years

• MDOT CPM Program certainly helping preserve existing pavements and delaying major R&R activities
Performance and Benefits of Surface Treatments on NPS Pavements

- **Sponsor:** FHWA Central Federal Lands Highway Division (CFLHD)
- **Contractor:** Applied Pavement Technology, Inc. (sub to Yeh and Associates, Inc.)
- **Time Period:** September 2010 – September 2012
- **Background**
Study Objectives

• Develop improved performance models addressing use of common surface treatments
  – Shift from generic models involving engineering judgment to objective analytical models that account for factors believed to affect treatment performance
  – Improve ability to identify optimal treatment timings

• Develop treatment monitoring guidelines
Research Approach

Data Compilation by FLHD

- Analyze Historical Pavement Condition Data
- Identify Gaps/Issues with Data
- Develop Climatic Zone and Traffic Levels
  - Develop Performance Models
    - Develop Long-term Evaluation Matrix
      - Develop Distress Rating Procedure
        - Summarize Study Findings and Recommendations in a Report / Presentation
## Parks Included

<table>
<thead>
<tr>
<th>Dry Freeze</th>
<th>Dry No-freeze</th>
<th>Wet Freeze</th>
<th>Wet No-freeze</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arches (UT)</td>
<td>Big Bend (TX)</td>
<td>Cuyahoga Valley (OH)</td>
<td>Great Smoky Mountains (TN)</td>
</tr>
<tr>
<td>Badlands (SD)</td>
<td>Death Valley (CA)</td>
<td>Lassen Volcanic (CA)</td>
<td>Natchez Trace (MS/TN)</td>
</tr>
<tr>
<td>Canyonlands (UT)</td>
<td>Joshua Tree (CA)</td>
<td>Natchez Trace (MS/TN)</td>
<td>Chickasaw (OK)</td>
</tr>
<tr>
<td>Lava Beds (CA)</td>
<td></td>
<td>Yosemite (CA)</td>
<td></td>
</tr>
<tr>
<td>Theodore Roosevelt (ND)</td>
<td></td>
<td>Acadia (ME)</td>
<td></td>
</tr>
<tr>
<td>Zion (UT)</td>
<td></td>
<td>Crater Lake (OR)</td>
<td></td>
</tr>
<tr>
<td>Grand Teton (WY)</td>
<td></td>
<td>Kings Canyon (CA)</td>
<td></td>
</tr>
<tr>
<td>John D. Rockefeller Jr. Memorial Parkway (WY)</td>
<td></td>
<td>Shenandoah (VA)</td>
<td></td>
</tr>
<tr>
<td>Rocky Mountain (CO)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Pavement Facility Types**

**Principal Pavements (PP):** Principal park road, connector park road, urban parkway

**Parking Areas (PA):**

**Other Pavements:** Special purpose road, administrative access road, restricted road
# NPS Use of Preservation Treatments

| Treatment                                                | No. of Projects/Sections
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip Seal, Type 1 (single-course)</td>
<td>190</td>
</tr>
<tr>
<td>Chip Seal, Type 2 (double-course)</td>
<td>53</td>
</tr>
<tr>
<td>Fog Seal</td>
<td>5</td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>87</td>
</tr>
<tr>
<td>Slurry Seal</td>
<td>70</td>
</tr>
<tr>
<td>Thin Hot Asphalt Concrete Pavement (HACP) Overlay</td>
<td>9</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>414</strong></td>
</tr>
</tbody>
</table>

1 Applied between 1993 - 2010
# Treatment Matrix

<table>
<thead>
<tr>
<th>Environment/Route Type</th>
<th>Dry Freeze</th>
<th>Dry No-Freeze</th>
<th>Wet Freeze</th>
<th>Wet No-Freeze</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Type</td>
<td>PP</td>
<td>PA</td>
<td>Other</td>
<td>PP</td>
</tr>
<tr>
<td>Chip Seal, Type 1 (Single Course)</td>
<td>55</td>
<td>16</td>
<td>29</td>
<td>18</td>
</tr>
<tr>
<td>Chip Seal, Type 2 (Double Course)</td>
<td></td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>Fog Seal</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>1</td>
<td>32</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>Slurry Seal</td>
<td>1</td>
<td>48</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Thin HACP Overlay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Extensive use (> 8 projects)
- Moderate use (4 to 8 projects)
- Limited use (1 to 3 projects)

PP = Principal Pavements
PA = Parking Areas
Other = Other Pavements
Performance Modeling

- Performance measures (0-to-100 scale)
  - Surface condition rating (SCR) (cracking, rutting, patching deducts)
  - Roughness condition index (RCI) (based on IRI)
  - Pavement condition rating (PCR) (composite of SCR & RCI)

- Pre- and post-treatment models using performance data from 2001-2010

- Realistic pre-treatment models developed for PP in 3 climatic zones, but reliable post-treatment models could not be developed

- Focus on performance jump and life extension (type I chip seals only)
**Pavement Life Extension (Type I Chip Seal, SCR)**

- **Principal Pavements**
  - Wet-Freeze: 4.1 Years
  - Dry Freeze: 9.3 Years
  - Dry No-Freeze: 10.5 Years
  - All: 11.5 Years

- **Other Pavements**
  - Wet-Freeze: 8.3 Years
  - Dry Freeze: 10.4 Years
  - Dry No-Freeze: 8.3 Years
  - All: 10.4 Years
Study Conclusions

• Original intent to model performance of surface treatments; however multiple problems encountered
  – Data collection equipment/protocol changes
  – Lack of rehabilitation dates
  – Limited performance data
  – Long cycle times leave many unknowns

• Alternate approach applied to Type I chip seals
  – Longer life extensions in dry-freeze vs wet-freeze climates

• Based on limited analysis, FLHD’s preventive maintenance program is extending service lives
Lessons Learned

• Target more frequent performance data collection cycle (e.g., 2 years instead of 4)
• If changes in data collection equipment/protocols occur, establish appropriate methods for linking historical data with new data
• Select good candidate projects for preservation treatments (pavements in fair-good condition only)
• Apply the treatments in optimal conditions
Thank You...Questions??

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CPM Treatments make the pavement smile, literally.

MDOT Report
http://www.trb.org/Finance1/Blurbs/168999.aspx
## NPS Data Collection Cycles

<table>
<thead>
<tr>
<th></th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
<th>Cycle 4</th>
<th>Cycle 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle</strong></td>
<td>ARAN van (paved), Mandli vehicle (unpaved)</td>
<td>ARAN van (large parks), Mandli vehicle (some small parks)</td>
<td>New ARAN van (large parks)</td>
<td>New ARAN van (large parks and some small parks)</td>
<td>PathRunner from Pathway Services, Inc. (small and large parks)</td>
</tr>
<tr>
<td><strong>Measures</strong></td>
<td>LC, TC, AC, bleeding, raveling, shoving, patching/potholes, IRI, rutting (no severities)</td>
<td>LC, TC, AC, patching/potholes, IRI, rutting, RCI, SCR</td>
<td>LC, TC, AC, patching/potholes, IRI, Rutting, RCI, SCR</td>
<td>LC, TC, AC, patching/potholes, IRI, rutting, RCI, SCR</td>
<td>LC, TC, AC, patching/potholes, IRI, rutting, RCI, SCR</td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td>Data compromised due to poor collection and processing, many distress ratings done through windshield surveys, deficient matrix, and lack of experience.</td>
<td>Noise in ultrasonic sensors resulted in erroneous rutting measurements, potholes were not filtered unless they exceeded 2 inches in depth, data reduction equations modified resulting in inconsistent measures.</td>
<td>Revised index equations used, resulting in inconsistent measures.</td>
<td>Data from Cycle 3 and Cycle 4 collected using same type of equipment, thereby providing some consistency.</td>
<td>Parking areas surveyed in small parks only, data collected only for principal park, urban parkway, and collector pavements. Data collection vehicle changed in Cycle 5. Data reduction equations modified from Cycle 4.</td>
</tr>
</tbody>
</table>
Post-1<sup>st</sup> CPM Treatment Data (First App)

### Number of Analysis Segments

<table>
<thead>
<tr>
<th>Category</th>
<th>Zone 1</th>
<th>Zone 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collectors</td>
<td>16 45 22 0</td>
<td>3 26 13 0</td>
</tr>
<tr>
<td>Minor Arterials</td>
<td>0 85 3 13</td>
<td>73 26 13 3</td>
</tr>
<tr>
<td>Principal Arterials</td>
<td>181 316 2 0</td>
<td>315 711 16 0</td>
</tr>
<tr>
<td>Interstates, Other Freeways</td>
<td>0 30 0 0</td>
<td>0 0 0 0</td>
</tr>
</tbody>
</table>

### Total

- Flexible Total: 1,041
- Composite Total: 1,969
- Rigid Total: 72
- TOTAL: 3,082
Post-2\textsuperscript{nd} CPM Treatment Data (Subsequent App)

Zone 2

- Collectors: 0 Flexible, 46 Composite, 32 Rigid
- Minor Arterials: 0 Flexible, 71 Composite, 247 Rigid
- Principal Arterials: 5 Flexible, 24 Composite, 333 Rigid
- Interstates, Other Freeways: 10 Flexible, 24 Composite, 360 Rigid

Zone 1

- Collectors: 4 Flexible, 46 Composite, 0 Rigid
- Minor Arterials: 0 Flexible, 102 Composite, 0 Rigid
- Principal Arterials: 0 Flexible, 224 Composite, 319 Rigid
- Interstates, Other Freeways: 3 Flexible, 29 Composite, 0 Rigid

Flexible Total: 1,132
Composite Total: 1,414
Rigid Total: 15
TOTAL: 2,561