A Pavement Management Primer

Presented To: Graduate Transportation Seminar (TRANS 691)

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Learning Objectives

- Describe the components of a pavement management system
- Describe the types of models that are used in a pavement management system
- Describe the use of pavement management techniques in a transportation agency
Approach

- Introduce Pavement Management Conceptually
- Introduce the Components of a Pavement Management System
- Discuss Each Component in More Detail
- Illustrate the Ways Pavement Management Results Can Be Used
A Conceptual Approach to Pavement Management
Pavement Management Is...

...a management approach used by personnel to make cost-effective decisions about a road network.

AASHTO Pavement Management Guide (2001)
A Pavement Management System Is...

...a set of tools or methods that assist decision-makers in finding optimum strategies for providing, evaluating, and maintaining pavements in a serviceable condition over a period of time.

Use of Pavement Management

- Identify and prioritize maintenance and rehabilitation needs
  - Select projects and treatments on an objective, rational basis
- Assist agencies in determining cost-effective treatment strategies
  - Allocate funds so an agency can get the most “bang for the buck”
  - Demonstrate impacts of alternate strategies
Managing Pavement Deterioration

- Cost-effective time for preventive maintenance
- Cost-effective time for minor rehabilitation
- Costly treatments needed
Pavement Management Components

- Network Inventory
- Network Definition
- Condition Assessment

Database

Analysis Tools

Reports

Pavement Management System

System Customization
- Models
- Costs
- Treatment Rules
Network Inventory

Type of Data to be Collected
- Physical characteristics
- Construction and maintenance history
- Traffic levels
- Climate information
- Soils information

Minimal Amount of Information Required
- Surface type
- Last construction date
- Physical dimensions
Network Definition

- Used to link network inventory information to a physical location in the field
- Determine section boundaries by evaluating the road characteristics. Sections should be similar in terms of surface type, structure, and traffic
- Identify beginning and end points and width
Network Definition – Local Agencies
Dynamic Segmentation and Concurrent Transformation

Traffic

Structure

Composite PCC Composite

50 100 400 200

Composite CT Composite

DS

PCC PCC PCC PCC

50 100 100 400 400 200

Composite Composite

CT

100 400

Composite Composite
Condition Assessment

All system recommendations are based on the current and predicted conditions of the sections in your network.

Therefore, the assessment of current condition MUST be objective and repeatable.

BUT, it must also match available resources.
Types of Pavement Condition Data Collected

- Surface distress (cracking, surface deform)
- Roughness (ride)
- Faulting
- Rutting
- Skid resistance
- Structure (pavement strength and deflection)
Approaches to Collecting Pavement Condition Data

- Manual
- Semi-automated
- Automated
Condition Indices

- Individual Indices
  - Ride Index
  - Structural Index
  - Cracking Index

- Composite Index
  - 40% Ride + 40% Structural + 20% Cracking
  - $\Sigma$ (Deduct points associated with a distress type, severity, and extent combinations)
RSL Calculation

Current Condition

Serviceable

Unserviceable

Threshold Value

Now

Time (years)

Condition Index

Performance Curve

Remaining Service Life
RSL Distribution

- Category I: 0 years
- Category II: 1-5 years
- Category III: 6-10 years
- Category IV: 11-15 years
- Category V: 15+ years
Database

- Inventory Data
- Condition Data
- Record Retrieval and Reporting
Capabilities Once The Database Is Established

- Inventory reports
- Condition ratings
  - By functional classification
  - By surface type
- Pavement distress data analysis
  - Overall condition
  - Rate of deterioration
  - Cause of deterioration
- Ranked lists of road needs
  - Worst first or weighted rankings
Condition Summary on a Network Basis

Existing Condition of Roadway System

<table>
<thead>
<tr>
<th>Road System</th>
<th>Percent of Road System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterials</td>
<td>Excellent: 60%</td>
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<tr>
<td></td>
<td>Good: 10%</td>
</tr>
<tr>
<td></td>
<td>Fair: 5%</td>
</tr>
<tr>
<td></td>
<td>Poor: 3%</td>
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<tr>
<td>Collectors</td>
<td>Excellent: 40%</td>
</tr>
<tr>
<td></td>
<td>Good: 20%</td>
</tr>
<tr>
<td></td>
<td>Fair: 15%</td>
</tr>
<tr>
<td></td>
<td>Poor: 5%</td>
</tr>
<tr>
<td>Residential/Local Access</td>
<td>Excellent: 50%</td>
</tr>
<tr>
<td></td>
<td>Good: 25%</td>
</tr>
<tr>
<td></td>
<td>Fair: 15%</td>
</tr>
<tr>
<td></td>
<td>Poor: 10%</td>
</tr>
</tbody>
</table>

Legend:
- Excellent
- Good
- Fair
- Poor
Condition Summary - By Route

PCR Values for State Route 286 Eastbound

PCR

Reference Marker

Trigger Value
Condition Reports Through a Map Link
Work Type Summary

Percent of Total Mileage Scheduled for Work in 2003

- Prelevel and Sealcoat
- Sealcoat Only
- Asphalt Overlay
- Not Scheduled
Building From a Database System

- To develop multi-year programs,
- To compare different options,
- To predict future conditions,

- You need a pavement management system that includes analysis models and multi-year programming capabilities
Analysis Models

- Pavement performance prediction models
- Treatment rules
  - When should a treatment be considered feasible?
  - What happens after the treatment is applied?
- Cost models
  - Budgets
  - Treatment cost models
Pavement Performance Models

- Group pavements by similar features (develop a family)
- Plot all condition and age (traffic) data for the sections in the family
- Use statistics to determine best fit curve through data
- If no data are available, use expert opinion to develop model
Expert Model

Ride (IRI) Performance Model -- All AC Pavements

$$y = \text{MIN} (100, 100 - 1.064x - 0.0262x^2 - 0.0023x^3)$$

$$R^2 = 1$$
Performance Model Using Actual Data

Date of Analysis: Fri Sep 6 09:34:35 2002
Family: Asp, Hi Vol, Flex
Index: RIDE
Year(s): 2001
Model Type: QUADRATIC
Analysis Method: GQ
Forced Endpoint: 25

25TH PERCENTILE
Coefficient Estimates:

| Value     | Std. Error | t value | Pr(>|t|) |
|-----------|------------|---------|---------|
| age       | -2.64123   | 0.71100 | -3.71483| 0.00114 |
| I(age^2)  | -0.05435   | 0.02844 | NA      | NA      |
| R-Squared | 0.059      |

50TH PERCENTILE
Coefficient Estimates:

| Value     | Std. Error | t value | Pr(>|t|) |
|-----------|------------|---------|---------|
| age       | -1.10583   | 0.60599 | -1.82484| 0.08104 |
| I(age^2)  | -0.11577   | 0.02424 | NA      | NA      |
| R-Squared | 0.238      |

75TH PERCENTILE
Coefficient Estimates:

| Value     | Std. Error | t value | Pr(>|t|) |
|-----------|------------|---------|---------|
| age       | -0.08989   | 0.57306 | -0.15686| 0.87673 |
| I(age^2)  | -0.15640   | 0.02292 | NA      | NA      |
| R-Squared | 0.35       |

R-square of NaN may occur when too many data points are at the maximum value.

Goodness-of-fit for the EXPERT CURVE relative to the 50th percentile = 0.302
If less than 1, the 50th percentile fit is better.
Treatment Rules: Type, Timing, Cost

- Excellent
  - Joint and crack sealing, surface seals
- Failed
  - Patching, thinner overlays
  - Thicker overlays
  - Reconstruction

Age
Treatment Impact Rules

What happens to the condition of a section after the treatment has been applied?

- Do conditions return to a perfect score? (Is the distress eliminated?)
- Does the severity of the distress change?
- Does it deteriorate the same way it did before the treatment was applied?
Modeling Treatment Impacts

Example: A chip seal is applied to a pavement section.
Cost Models

◊ Treatment Costs
  ■ Based on recent bid documents
  ■ May vary based on certain factors (location, street network, and so on)

◊ Budgets
  ■ Funds available for each analysis year
  ■ Some agencies have separate budgets for maintenance and rehabilitation activities
Analysis Approaches

- Once needs are identified, there must be a way of prioritizing the list and determining which projects should be funded
- Three approaches
  - Ranking
  - Multi-Year Prioritization
  - Optimization
Ranking

- Most simplistic of the approaches
- Traditionally used in worst-first scenarios
- Often doesn’t use predictions of condition
- In most cases, alternate programs are not considered
## Ranking Example

<table>
<thead>
<tr>
<th>Section</th>
<th>Condition</th>
<th>Treatment</th>
<th>Cost (mil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>67A</td>
<td>67</td>
<td>Minor</td>
<td>1</td>
</tr>
<tr>
<td>67B</td>
<td>82</td>
<td>PM</td>
<td>0.5</td>
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<tr>
<td>67C</td>
<td>52</td>
<td>Major</td>
<td>3</td>
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<tr>
<td>14A</td>
<td>71</td>
<td>Minor</td>
<td>2</td>
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<tr>
<td>14B</td>
<td>74</td>
<td>Minor</td>
<td>1.5</td>
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<tr>
<td>Univ1</td>
<td>85</td>
<td>PM</td>
<td>0.5</td>
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</tbody>
</table>
### Results for $4 Million Budget

<table>
<thead>
<tr>
<th>Section ID</th>
<th>Ranking</th>
<th>Condition Level</th>
<th>Treatment</th>
<th>Cost ($millions)</th>
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<tbody>
<tr>
<td>67C</td>
<td>1</td>
<td>52</td>
<td>Major</td>
<td>3</td>
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<tr>
<td>67A</td>
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<td>67</td>
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<td>1</td>
</tr>
<tr>
<td>14A</td>
<td>3</td>
<td>71</td>
<td>Minor</td>
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<tr>
<td>14B</td>
<td>4</td>
<td>74</td>
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<td>1.5</td>
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<tr>
<td>67B</td>
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<tr>
<td>Univ1</td>
<td>6</td>
<td>85</td>
<td>Prev. Maint.</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Multi-Year Prioritization

- Moderate level of sophistication
- Allows multiple alternatives to be considered during a multi-year program
- Fairly easy to explain and justify recommendations
- Results in “near optimal” solutions
Treatment Options in MYP

- Trigger Point for Treatment 1
- Age or Traffic Loads
- Pavement Condition Index
- Existing Performance
- Treatment 1 in Years X and Z at $ Cost
- Treatment 2 in Year Y at $S Cost
- Trigger Point for Treatment 2

Applied Pavement Technology
Benefit/Effectiveness Calculation

Existing Pavement Performance

Pavement Condition Index

Age or Traffic Loads

Trigger Limit

Benefit

Predicted Pavement Performance
Optimization

- Most sophisticated approach
- Only used by a few states
- Two step process
  - First, set optimal program strategy recommendations
  - Second, select projects to fit strategy
# Markov Transition Probability Matrix

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<tr>
<th>Current State</th>
<th>Future State</th>
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<tr>
<td></td>
<td>1</td>
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<td>1</td>
<td>0.2</td>
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<td>3</td>
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</table>
Example Network Performance

Projected Performance

Steady State Begins

Proportion of Roads

Days
Linear Programming

Variable Number 2

Objective Functions

Feasible Solutions

Constraints

Variable Number 1
Dynamic Programming

Decision Flow

Solution Flow

Begin

End

(Costs)
The Use of Pavement Management Tools

- Identify and prioritize maintenance and rehabilitation needs
- Evaluate the impact of various programs through a comparison of conditions, backlog, or another measure
- Establishing pavement condition targets
- Setting budget needs
Network Level Performance Based on 4 Funding Scenarios
Willmar District Pavement Management
All Scenarios Based on Using Programmed Projects
October, 1995

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NO-REHAB</th>
<th>$15 MILLION</th>
<th>$18 MILLION</th>
<th>$21 MILLION</th>
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</table>

<table>
<thead>
<tr>
<th>% PQI &lt; TRIGGER</th>
<th>NO-REHAB</th>
<th>$15 MILLION</th>
<th>$18 MILLION</th>
<th>$21 MILLION</th>
</tr>
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<tbody>
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<tr>
<td>2005</td>
<td>79</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>

Impact Analysis

Average PQI

% Below Trigger Value

Graphs showing the average PQI and percentage below trigger value over the years for different funding scenarios.
Goal Setting and Measuring

Percent of Network in 'Very Good' and 'Good Condition'

Year

Percent of Total Sections >70

- Various Yearly Budgets
- Target of 93% > 70
Backlogged Needs

Total Backlog ($) vs. Time

Year

Total Backlog, $ (millions)

2002 2003 2004 2005 2006 2007 2008

Various Yearly Budgets
Communicating Budget Needs

Airport Pavement Management Study Underway

The Georgia Department of Transportation (GDOT) has initiated a statewide airport pavement management study. The study will involve an initial analysis of existing pavement conditions at all 46 of Georgia's public airports and provide a detailed assessment of the current state of pavement management systems (PMS). The study will also include the development of an overall pavement management strategy for the state's airports.

Communicating the need for funding is an important aspect of the study. The GDOT has developed a comprehensive infrastructure maintenance and rehabilitation plan for all airports, which will be used to develop a strategy for maintaining and improving the state's airport pavement networks.

The GDOT has requested a commitment from airports to develop and implement a comprehensive pavement management strategy. This commitment is critical to ensuring the successful implementation of the study and the continued improvement of Georgia's airport pavement management systems.

For more information on the study or to access the latest reports and updates, please contact the GDOT's Aviation Department at 770-414-7610 or visit their website at www.dot.ga.gov/aviation.
Establishing a Feedback Loop

- A pavement management system must continue to reflect observed trends and agency practices
  - Update models over time
  - Keep database current
- Tie in pavement management information to others in the agency
  - Design
  - Maintenance
Link to Asset Management

Expanding the management approach to include other physical assets

- Trade-off decisions
- Assist in calculating asset value
Benefits of Pavement Management

- More efficient use of available resources
- Ability to justify funding needs
- More accurate and accessible information on the pavement network
- Ability to track pavement performance
- Ability to show impacts on condition
- Improved communication

AASHTO Pavement Management Guide (2001)