Development of Pavement Performance Prediction Models for LADOTD PMS

Mohammad Jamal Khattak, Ph.D., P.E.,
Associate Professor
Department of Civil Engineering,
University of Louisiana at Lafayette
Layout

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- Pavement Performance Prediction Models
- Network Condition Assessment
- Remaining Service Life
- Summary and Conclusions
PMS Study-LTRC 04-2P

Introduction

- Two Phase PMS study was initiated by LADOTD
  - Cost effective way to incorporate the PMS into LA DOTD’s regular operation
  - Make the information in the PMS usable for engineers within the department
Objectives

- Identify the needs of the PMS users at LADOTD
- Establish a unified roadway identification system acceptable to all PMS users
- Evaluate and update the existing pavement condition assessment, and treatment selection models
- Evaluate and update the existing pavement performance prediction models
Pavement Performance Prediction

Distress Index

Pavement Age

Preventive Maintenance

Minor Rehabilitation

Major Rehab/Reconstruction
Existing LADOTD Pavement Performance Models

- Pavement Performance Prediction Models
  - Based on Distress Index & Pavement Age
  - Highway Classification
    - Interstate, Collectors and Arterials
  - Pavement Type
    - Flexible, JCP, COM and CRC
  - Each Distress Type
Existing LADOTD Pavement Performance Models

- **Index Scale (I)**
  - 0 to 100 (100 being perfect)
  - Calculated based on deduct points

- **Deduct Points (DP)**
  - Type of distress
  - Extent of the distress
  - Severity level
    - Low severity
    - Medium severity
    - High severity

\[ I = 100 - \Sigma(DP) \]
Existing LADOTD Pavement Performance Models

- Regression based models for distress indices as function of Age

- Transformation functions
  - Roughness Index: Polynomial function
  - All indices for CRCP: Power function
  - Rutting Index: Exponential function
  - All other: Linear function
Development of Pavement Performance Models
Development of Pavement Performance Models

- DATA for Pavement Performance Modeling
  - Distress Index Data for 1/10\text{th} mile for each control section (1995-2005)
  - Historical Data (TOPS)
    - Last Resurface date (Surface Age)
    - Construction/Reconstruction date (Age)
Pavement Performance Model

Index

Threshold

Surface Age-1

Surface Age-2

Age

0 5 10 15 20

Years
## Distribution of Element IDs

(1/10\textsuperscript{th} mile)

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Highway Classification (EL-ID)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IHS</td>
<td>NHS</td>
</tr>
<tr>
<td>Flexible (Asphalt)</td>
<td>3,764</td>
<td>22,387</td>
</tr>
<tr>
<td>Composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JPC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRC</td>
<td>586</td>
<td>117</td>
</tr>
<tr>
<td>Total</td>
<td>17,866</td>
<td>36,921</td>
</tr>
</tbody>
</table>

\[5 \times 188,580 = 942,900\]
Pavement Performance Models

- **Statistical Analyses**
  - **Statistical Programming Using “R” Program**
    - A program was developed
    - Data Sorting
    - Statistical Analysis and Modeling
    - Program was validated and executed

- **Models for each Highways Classification**
  - Interstate Highway System (IHS)
  - National Highway System (NHS)
  - State Highway System (SHS)
  - Regional Highway System (RHS)
Pavement Performance Models

- **Statistical Analyses (cont’d)**
  - **Pavement Type**
    - Asphalt (ASP)
    - Jointed Concrete (JCP)
    - Composite (COM)
    - Continuously Reinforced Concrete (CRC)
  - **Distress Type**
    - IRI, Fatigue, Patching, Rutting, Longitudinal Cracking, Transverse Cracking, etc
  - **Four Transformation Functions (Model types)**
    - Power function
    - Two degree polynomial
    - Logarithmic function
    - Exponential Function
Shifted Data

Asphalt Pavement (SHS) Control Section 056-30 (Sorted Data)

RTI = 100 - DP

Surface Age ($t_{SA}$), years

Upper 1/3rd Zone
Middle 1/3rd
Lower 1/3rd Zone
Four Models of “R” Program

DP = 100 - I
Asphalt Pavement (SHS)  
Control Section 056-30  
(Sorted Data)

\[ RTI = 100 - b \cdot (t_{SA})^a \]
Asphalt Pavement (SHS)
Control Section 056-30

Existing Model

43% of the values are within (+) 2.5% Error
66% of the values are within (+) 5.0% Error
78% of the values are within (+) 7.5% Error
87% of the values are within (+) 10.0% Error
94% of the values are within (+) 15.0% Error

Line of Equality
Asphalt Pavement (SHS)
Control Section 056-30
(Predicted vs. Actual)

81% of the values are within (\pm) 2.5% Error
89% of the values are within (\pm) 5.0% Error
95% of the values are within (\pm) 7.5% Error
98% of the values are within (\pm) 10.0% Error
100% of the values are within (\pm) 15.0% Error
Jointed Plain Concrete Pavement (NHS)
Longitudinal Cracking
Control Section 019-02

Surface Age

Index

Sorted Data

Upper 1/3\textsuperscript{rd}

Middle 1/3\textsuperscript{rd}

Lower 1/3\textsuperscript{rd}
Existing Model

Jointed Plain Concrete Pavement (NHS)
Longitudinal Cracking
Control Section 019-02

16% of the values are within (+) 2.5% Error
26% of the values are within (+) 5.0% Error
35% of the values are within (+) 7.5% Error
43% of the values are within (+) 10.0% Error
57% of the values are within (+) 15.0% Error
Jointed Plain Concrete Pavement (NHS)
Longitudinal Cracking
Control Section 019-02

New Model

41% of the values are within (+) 2.5% Error
57% of the values are within (+) 5.0% Error
70% of the values are within (+) 7.5% Error
76% of the values are within (+) 10.0% Error
82% of the values are within (+) 15.0% Error
Generalized models were developed

- Based on Distress Index and Age
- Highway Classification
- Pavement Type
- Distress Type
- Example: *IHS-ASP-Fatigue Model, etc.* ....

Fundamental concept of rate of deterioration was applied
Roughness Index Generalized Model (NHS)

\[ y = 0.27x^{0.35} \]

\[ R^2 = 0.92 \]
Roughness Index Generalized Model (NHS)

\[ RI = 100 - 10 \left[ b_1 (t_A)^{a_1} \log(t_A) + C \right] \]

OR

\[ RI = 100 - b_{avg} \cdot (t_A)^{a_{avg}} \]

The generalized model based on the age of the pavement can be used to determine the deterioration of a new road with possible successive rehabilitation actions during its life span.
Existing Model
National Highway System (NHS)
Flexible Pavement

No data points = 14000

- 44% of the values are within (±) 2.5% Error
- 60% of the values are within (±) 5.0% Error
- 70% of the values are within (±) 7.5% Error
- 78% of the values are within (±) 10.0% Error
- 86% of the values are within (±) 15.0% Error
National Highway System (NHS) Flexible Pavement

New Model

53% of the values are within (+) 2.5% Error
67% of the values are within (+) 5.0% Error
76% of the values are within (+) 7.5% Error
81% of the values are within (+) 10.0% Error
87% of the values are within (+) 15.0% Error

No data points = 14000
Network Condition Assessment
NHS Condition-Existing Model

Existing (2005) and Predicted (2010) Condition

- Existing Condition 2005
- Predicted Condition 2010

2005 35% @ Maintenance
2010 91% @ Maintenance
Existing (2005) and Predicted (2010) Condition

2005 35% @ Maintenance
2010 68% @ Maintenance

Roughness Index

Frequency

NHS Condition-New Model

Predicted Condition 2010
Existing Condition 2005
Model Comparison-NHS Condition

Maintenance

Percent of NHS Network

--- | --- | --- | ---
35 | 91 | 65 | 64
Model Comparison-NHS Condition

Major Rehab/Reconstruction

Percent of NHS Network

- Network Condition (2005): 5
- Existing Generalized Model (2010): 36
- New Control Section Model (2010): 17
Remaining Service Life (RSL)
Remaining Service Life (RSL)

- **RSL Concept**

  Good Indicator of Prediction
  1. Index Value
  2. Rate of Deterioration

  ![Graph showing RSL Concept]

  - Index
  - Threshold
  - Surface Age
  - Year

  - Sections 1 and 2
  - RSL1 and RSL2
National Highway System
(Flexible Pavement)

- 1534 Sections $\geq$ 30 RSL
- 633 Sections < 30 RSL

Remaining Service Life (RSL)

Frequency
Summary and Conclusions

- Most existing pavement performance models were developed using the initial few years of distress data.
  - Tends to either under predict or over predict the pavement condition.
  - Calibrating/ Developing models based on available 10 years data was required to enhance the predicting capabilities of LADOTD PMS.
Summary and Conclusions

- **Index based pavement performance models were developed**
  - Control sections that exhibited good performance data and historical records.
  - Three categories; upper, middle and lower 1/3rd percentile
  - The results indicated that predicted values exhibited good agreement with the actual values.
Summary and Conclusions

- Fundamental relationship between the pavement rate of deterioration and pavement age was evaluated
  - The increase in age of the pavement the rate of deterioration increases.
  - The results of the Generalized models analyses showed good agreement of predicted index values.
  - Furthermore, approximately, 70-95% of data exhibited within 7.5% error between the predicted and observed values.
Summary and Conclusions

- The developed models can be used to:
  - Determine the health of the pavement network
    - Index Predictions
    - Remaining service life
  - Enhances the PMS capabilities in predicting
    - Pavement conditions
    - Maintenance activities
    - Major Rehab/Reconstruction activities
    - Treatment selection
Thanks!