Performance Measures for Making Pavement Preservation Decisions

David Luhr
Pavement Management Engineer
Washington State DOT
Performance Measures as Tools

• Project Decision Support
  - Where, When, and How for pavement decisions

• Accountability & Communication
  - achieving standards, reports to legislature & public
  - stewardship, protecting infrastructure investment

• Forecasting Needs & Risks
  - funding needs, evaluation of risk

• Learning
  - continual improvement of methods & procedures
Performance Measures within what Context?

• Historical?
• Future Projection?

• Project Level?
• Network Level?

• Agency Perspective?
• User Perspective?
Pavement Performance Measures

What is current physical condition of pavement?

• Distress (cracking, rutting, raveling, faulting, etc.)
• Profile - Roughness (IRI)
• Friction (Skid Number, macrotexture)
• Structure (deflection, seismic response)
Pavement Performance Measures

How is road performing for users?

• Roughness (IRI)
• User cost (user delay, user operating cost)
• Freight damage
• Safety (pavement related)
§150. National goals and performance management measures

(a) DECLARATION OF POLICY.—Performance management will transform the Federal-aid highway program and provide a means to the most efficient investment of Federal transportation funds by refocusing on national transportation goals, increasing the accountability and transparency of the Federal-aid highway program, and improving project decisionmaking through performance-based planning and programming.
Cost-Effectiveness

• Evaluates the cost of acceptable pavement performance ($/lane-mile/year)

• Simpler than Benefit/Cost analysis, since difficult to express benefit of pavement performance in terms of dollars
Cost-Effectiveness

“...the most efficient investment...”

• Annual Cost ($ / lane-mile / year of life)

• Historical Cost of Acceptable Pavement Performance
  • Actual historical cost ($/LMY)

• Expected Cost of Future Pavement Rehab
  • Projected LCCA ($ /LMY)
Equivalent Uniform Annual Cost (EUAC)

\[
EUAC = P \frac{\frac{\text{NPV}}{i (1+i)^n}}{(1+i)^n - 1}
\]

where

P = Present Value of all costs

i = Discount Rate

n = number of years
Advantages of EUAC

1) A simple measure that can be directly compared with a different project, or statewide average

2) Easier to calculate (no need to add multiple performance periods)

3) Salvage Value does not need to be considered
## Typical Cost-Effectiveness Comparison

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Treatment Category</th>
<th>Treatments</th>
<th>Agency Cost ($/LM)</th>
<th>Life Extension (years)</th>
<th>EUAC(_{0%}) ($/LMY)</th>
<th>EUAC(_{4%}) ($/LMY)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chip Seal</strong></td>
<td>Maint.</td>
<td>Crack sealing, patching</td>
<td>$2,500</td>
<td>2</td>
<td>$1,250</td>
<td>$1,325</td>
</tr>
<tr>
<td></td>
<td>Rehab</td>
<td>Resurfacing</td>
<td>$45,000</td>
<td>9</td>
<td>$5,000</td>
<td>$6,052</td>
</tr>
<tr>
<td></td>
<td>Reconst.</td>
<td>Rebuild</td>
<td>$200,000</td>
<td>14</td>
<td>$14,286</td>
<td>$18,934</td>
</tr>
<tr>
<td><strong>Asphalt</strong></td>
<td>Maint.</td>
<td>Crack sealing, patching</td>
<td>$5,000</td>
<td>3</td>
<td>$1,667</td>
<td>$1,802</td>
</tr>
<tr>
<td></td>
<td>Rehab</td>
<td>Resurfacing</td>
<td>$225,000</td>
<td>15</td>
<td>$15,000</td>
<td>$20,237</td>
</tr>
<tr>
<td></td>
<td>Reconst.</td>
<td>Remove &amp; Replace</td>
<td>$1,000,000</td>
<td>20</td>
<td>$50,000</td>
<td>$73,582</td>
</tr>
<tr>
<td><strong>Concrete</strong></td>
<td>Rehab</td>
<td>Grinding, slab replacement</td>
<td>$400,000</td>
<td>15</td>
<td>$26,667</td>
<td>$35,976</td>
</tr>
<tr>
<td></td>
<td>Reconst.</td>
<td>Remove &amp; Replace</td>
<td>$2,500,000</td>
<td>50</td>
<td>$50,000</td>
<td>$116,376</td>
</tr>
</tbody>
</table>
LCCA: Asphalt and Chip Seal

Do Nothing ??

Preservation ($$) ??

Rehab ($$$) ??

Years

Condition Indexes

Index value 45 ~ 50

Optimum time for Rehab

Excessive Vehicle Operating Costs

Excessive Agency Construction Costs

Reconstruction ?? ($$$$$$)
Replacement Analysis

Decision Analysis to consider:
- Do Nothing (no replacement)
- Maintenance
- Rehabilitation
- Reconstruction

If proposed alternative results in lower annual cost, then make decision for replacement
EUAC Replacement Analysis

Lowest Total Annual Cost is time for

- EUAC Rehab Construction
- EUAC Maintenance
Calculation of EUAC for an asphalt pavement resurfacing ($250k for 12 year period).

Spending additional $5k on maintenance in year 10 and $15k in year 15 results in EUAC that is $3.1k less (12% reduction in annual cost).
(Assumed Discount Rate 4%)
Breakeven Analysis

Spending $5k on maintenance in year 10 and $71.2k in year 13 to achieve a 15 year life is equivalent to EUAC of $26,638/yr. (Assumed Discount Rate 4%)
Performance Measures as tools in Pavement Management

- **Decision Support**
  - Where, When, and How for pavement decisions

- **Accountability & Communication**
  - achieving targets, reports to legislature & public
  - stewardship, protecting infrastructure investment

- **Forecasting Needs & Risks**
  - funding needs, evaluation of risk

- **Learning**
  - continual improvement of methods & procedures
Historical ACP $ / LMY by Region
Performance Period

- Eastern: $20,018
- North Central: $20,347
- Northwest: $21,889
- Olympic: $19,985
- South Central: $20,754
- Southwest: $27,836
- Statewide: $21,237
Pavement Performance Measures - Network Level

How well is infrastructure being managed (past and future)?

- Remaining Service Life (RSL)
- Asset Sustainability Ratio
- Accrued cost of deferred maintenance/rehabilitation (Deferred Preservation Liability)
Remaining Service Life (RSL)

• Measures the pavement life (years until due for rehabilitation) of each section over the entire network (expressed as % of typical pavement life)

• Healthy system has remaining service life of 40 – 60 percent
  • In an ideal system, the entire system would have an average remaining service life equal to 50% of the total average pavement life
If Planned Funding continues, Remaining Service Life plunges.
Asset Sustainability Ratio

• Measures how well WSDOT’s pavement replenishment is keeping up with pavement wear.

• Illustrates how much life was put back into the pavement system verses how much was consumed in a given year (units of lane-mile years).

• Consumption (for WSDOT flexible pavements) is 16,000 lane-mile years (per year)

• Target is Ratio of 1.0
Deferred Preservation Liability

- Is an estimate of the funding necessary to address the backlog of deferred pavement rehabilitation

- Takes into consideration higher costs as pavement condition gets worse (and needs more extensive repair)
Deferred Preservation Liability
(millions of dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>Liability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>$154</td>
</tr>
<tr>
<td>2011</td>
<td>$176</td>
</tr>
<tr>
<td>2012</td>
<td>$220</td>
</tr>
<tr>
<td>2013</td>
<td>$352</td>
</tr>
<tr>
<td>2014</td>
<td>$413</td>
</tr>
<tr>
<td>2015</td>
<td>$505</td>
</tr>
<tr>
<td>2016</td>
<td>$703</td>
</tr>
<tr>
<td>2017</td>
<td>$826</td>
</tr>
<tr>
<td>2018</td>
<td>$1,118</td>
</tr>
<tr>
<td>2019</td>
<td>$1,831</td>
</tr>
<tr>
<td>2020</td>
<td>$2,355</td>
</tr>
<tr>
<td>2021</td>
<td>$3,048</td>
</tr>
<tr>
<td>2022</td>
<td>$3,989</td>
</tr>
</tbody>
</table>
## Decision Support
- Pavement Condition
- Cost-Effectiveness
- Remaining Service Life

<table>
<thead>
<tr>
<th></th>
<th>Future</th>
<th>Historic</th>
<th>Project Level</th>
<th>Network Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Condition</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost-Effectiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remaining Service Life</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Forecast Needs & Risks
- Pavement Condition
- Remaining Service Life
- Deferred Preservation Liability

<table>
<thead>
<tr>
<th></th>
<th>Future</th>
<th>Historic</th>
<th>Project Level</th>
<th>Network Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Condition</td>
<td>✔️</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remaining Service Life</td>
<td></td>
<td></td>
<td></td>
<td>✔️</td>
</tr>
<tr>
<td>Deferred Preservation Liability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Accountability & Communication
- Pavement Condition
- Asset Sustainability Ratio
- Cost-Effectiveness

<table>
<thead>
<tr>
<th></th>
<th>Future</th>
<th>Historic</th>
<th>Project Level</th>
<th>Network Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Condition</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Asset Sustainability Ratio</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Cost-Effectiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Learning
- Cost-Effectiveness
- Remaining Service Life
- Pavement Condition

<table>
<thead>
<tr>
<th></th>
<th>Future</th>
<th>Historic</th>
<th>Project Level</th>
<th>Network Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost-Effectiveness</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Remaining Service Life</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Pavement Condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
David Luhr
State Pavement Management Engineer
LuhrD@wsdot.wa.gov
(360) 709-5405