Life Cycle Cost Analysis for Pavements: An Overview

March 28, 2012

Jerry Reece, Executive Director
North Carolina Concrete Pavement Assn
An affiliate of the ACPA
Greensboro, NC
Learning Objectives

- What is a LCCA?
- Why use the LCCA approach?
- Who is using LCCA?
- What is Federal policy?
- Overview of 5-step LCCA process
- Important factors and considerations
- NC’s use of LCCA
When evaluating competing project designs, engineers are often confronted with the option of using alternative materials with wide ranges of design or useful life!
Background

Comparison often complicated because:

- Lowest initial cost may not be the most effective
- Must project all costs of competing alternatives
- Account for future inflation and time-value of money

Objective: To determine the lowest Long-Term cost of the competing design alternatives
What is LCCA?

Life-Cycle Cost Analysis is a process for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, user, reconstruction, rehabilitation, restoring, and resurfacing costs, over the life of the project segment.

Source: Transportation Equity Act for the 21st Century
What is LCCA?

In short, LCCA is the process of determining the ownership cost of any roadway segment over a prescribed number of years.....asphalt or concrete.
Why use the LCCA approach?

- Make better transportation investment decisions
- Assist in determining the lowest cost way to meet the performance objectives of the project.
- Dwindling resources and reduced purchasing power makes the employment of LCCA even more critical.
Why use the LCCA approach?

- Reduced purchasing power...

(source: US BLS)
Who is using LCCA?

- South Carolina DOT SPR 656 – Preliminary
- 33 states and 2 provinces responded...
FHWA does not require the use of LCCA, but recommends its use as a matter of “GOOD Practice”
Life Cycle Cost Analysis

THE PROCESS *
The LCCA Process...

Five steps...

1. Establish design alternatives
2. Determine timing of activities
3. Estimate agency and user costs
4. Compute life-cycle costs
5. Analyze results
LCCA: Five-Step Process

1. Establish design alternatives
   - Asphalt versus concrete pavement?
   - Requires equal BENEFITS to the user, i.e. same level of service over the analysis period
   - DarwinME design methods predict the long term performance of each pavement type
LCCA: Five-Step Process

2. Determine timing of activities (real data)

When will the future maintenance and rehabilitation costs be incurred?

(Graphic: FHWA)
MECHANISTIC EMPIRICAL PAVEMENT DESIGN GUIDE (MEPDG)

New design procedure based on advanced models & actual field data collected across the US
Adopted by AASHTO in April 2011 as its Official Pavement Design Guide

MEPDG Facts

State-of-the-practice design procedure based on advanced models & actual field data collected across the US

- Adopted by AASHTO in 2008 as the Interim Pavement Design Guide
- New and rehabilitated pavements
- Calibrated with more than 2,400 asphalt and concrete pavement test sections across the U.S. and Canada, ranging in ages up to approximately 37 years

Based on mechanistic-empirical principles that account for site specific:

- Traffic
- Climate
- Materials
- Proposed structure (layer thicknesses and features)

Provides estimates of performance during the analysis period

- Performance predicted for cracking, faulting, IRI, cumulative damage, load transfer, and punchouts (CRCP)
- Can match rehabilitation activities to performance

MEPDG gives estimates of performance so designer can evaluate different design features

MEPDG Performance Curve

- Predicted Cracking
- Percent slabs cracked
- Cracked at specified reliability
- Limit percent slabs cracked

Design life is when hit predefined level distress level

Blue Line - The actual level of distresses predicted (the most likely distress level)

Magenta Line – The level of distresses at the given reliability level (i.e. 90%)

Red Line - Defined Failure Limit. Hitting this distress level does not mean the pavement is no longer functioning. It is the level defined as to when major rehabilitation is needed (i.e. patching & DG or overlay).
FINAL PAVEMENT PERFORMANCE COMPARISONS
Most agencies do repairs when IRI ~ 120 in/mi (red dotted)

Asphalt Design (From NCDOT)

<table>
<thead>
<tr>
<th>Estimated Costs</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Cost</td>
<td>$24,006,921.20</td>
</tr>
</tbody>
</table>

Concrete Designs

<table>
<thead>
<tr>
<th>Estimated Costs</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.5&quot; JPCP / 6&quot; Granular Base</td>
<td>$21,008,822.94</td>
</tr>
<tr>
<td>9&quot; JPCP / 6&quot; Granular Base</td>
<td>$21,334,588.71</td>
</tr>
<tr>
<td>9&quot; JPCP / 1.5 AC/ 4&quot; Granular Base</td>
<td>$23,205,188.53</td>
</tr>
<tr>
<td>9&quot; JPCP / 3&quot; AC</td>
<td>$23,912,222.31</td>
</tr>
<tr>
<td>9&quot; JPCP / 4&quot; AC</td>
<td>$25,934,999.56</td>
</tr>
</tbody>
</table>

9" AC / 8" ABC / Subgrade

Repair required at Year 10 (in line with NCDOT LCCA practices)

No structural repair required (in line with NCDOT LCCA practices)
3. **Estimate agency costs and user costs**
   - Exclude elements that are same for all alternatives
   - Agency costs are easier to establish – MUST base on historical data!
   - User costs may include: vehicle, delay and crash costs!
**LCCA: Five-Step Process**

4. **Compute life-cycle costs (Present Worth)**

\[
\text{Present Worth of Costs} = \sum_{k=0}^{N} (\text{Cost}_k) \times \left( \frac{1}{(1 + d)^{n_k}} \right)
\]

- \( N \) = length of analysis period
- \( d \) = discount rate
- \( n_k \) = year of expenditure

*Present Worth Factor*
LCCA – Present Worth Analysis!

Discounts all future costs (and benefits) to the present

Cost

Initial Cost

Rehabilitation Costs

Maintenance Costs

Present Worth

RSL Value

ACPA Education & Training

Making the world’s best pavements even better!
5. Analyze the results

How do agency costs compare?
How do user costs compare?
Can trade-offs be made?

LCCA is a decision support tool – results of the LCCA are not decisions in and of themselves.

(Federal Register, September 18th, 1996)
Life Cycle Cost Analysis

FACTORS
LCCA: Important Factors

- Comparable sections (real data)
- Analysis period
- Time to rehab/maintenance (real data)
- Agency Costs versus User Costs (real data)
- Remaining Service Life Value
- Discount Rate
- Risk and uncertainty – safety, material escalation

Five step process...
1. Establish design alternatives
2. Determine timing of activities
3. Estimate agency and user costs
4. Compute life-cycle costs
5. Analyze results
In addition several other sources were extremely helpful, including:

Historic usage of LCCA in North Carolina
“Life cycle cost analysis is performed when both a flexible and rigid pavement type is considered for a given project.”

Historically, both asphalt and concrete are considered for interstate routes, while asphalt is typically the single choice for non-interstate routes.
NC has nation's 2\textsuperscript{nd} largest road system – 79,200 miles

- High-Type (heavy duty) roads – 21,348 miles
- High-type Interstate roads – 1,507 miles (7.1%)
- High-Type Non-interstate roads - 19,841 miles (92.9%)

Comparative Life Cycle Cost Analysis is generally not performed on non-interstate routes.
How can NC benefit from LCCA usage?

- Construction & maintenance costs become more predictable and programmable for the agency
- The agency is able to take advantage of market conditions that reduce pavement costs
- Pavement comparison induces competition which lowers costs of either roadway type
- Use of new design methods & LCCA procedures, optimizes pavement longevity, decreasing construction zones, lowering user cost and improving safety
Advantages of Concrete Pavements

Longest total life span – some states performing 60-yr analysis periods on high volume roads

Fewer maintenance cycles – 28 -30 yrs after construction

Lowest Life Cycle Cost on medium to heavy-duty roads

Construction pricing has decreased 35-45% in last 5 years

All materials manufactured locally – totally recyclable

Fixed cost of construction – no material indexing

New maintenance techniques make older PCC pavements perform like new – diamond grinding, dowel bar retrofit
Does Life Cycle Work for Maintenance?

I-26 Asheville, NC

Built 1967  Rehab 1993 & 2009
Design 9000ADT  Today 36,000ADT  18% Trucks
LCCA Maintenance Options

Asphalt Method

Overlay with Nova chip Asphalt
Mill and Re-overlay in 8-years
Mill and Re-overlay in 16-years
Mill and Re-overlay in 24-years

Concrete Method

Grind / Reseal Joints- Year 26
Patch / Grind / Reseal – Yr 42

Total expected life with both options is 50+ years
I-26 Asheville, NC
Standing the test of time....

Hwy 21 Bypass - 48 years old
Standing the test of time......

Hwy 32 – Chowan Co
80-years old
What effect does Life Cycle Cost Analysis & Competition have on bid pricing?

$\$\$\$\$
## The Missouri and Louisiana Experience

**LCCA and Competition**

<table>
<thead>
<tr>
<th>Missouri</th>
<th>Louisiana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of bids/job increased</td>
<td>Number of bids/job increased</td>
</tr>
<tr>
<td>from 3.7 (2005) to 5.5 (2009)</td>
<td>from 2.6 to 3.9 (post-Katrina)</td>
</tr>
<tr>
<td>Paving Prices Decreased</td>
<td></td>
</tr>
<tr>
<td>Asphalt Decreased 5.1%</td>
<td>Engineer’s Estimate vs. Bid</td>
</tr>
<tr>
<td>Concrete Decreased 8.8%</td>
<td>Alternate bids – 9% below est.</td>
</tr>
<tr>
<td></td>
<td>Non-alternate – 20% above est.</td>
</tr>
<tr>
<td></td>
<td>In 2008, LA saved $62.5-million</td>
</tr>
<tr>
<td></td>
<td>Cost to Benefit Ratio of Money Saved vs.</td>
</tr>
<tr>
<td></td>
<td>Additional Engr. Cost was 1000:1</td>
</tr>
</tbody>
</table>

In 2008, LA saved $62.5-million
Conclusions

- The use of LCCA provides roadway ownership cost.
- Life Cycle calculations are valid for concrete or asphalt.
- Fair design is vital to proper comparison.
- New design methods can predict pavement performance.
- Policy revisions can facilitate greater LCCA usage.
- Use of LCCA in combination with an alternate bid process can save significant taxpayer money.
- Maintenance solutions can benefit from LCCA calcs.
Questions???