Life Cycle Cost Analysis for Pavements:

An Overview

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

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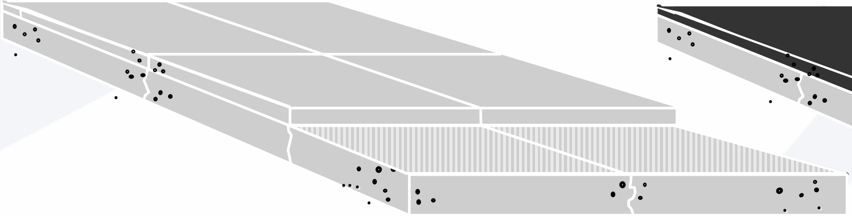
Learning Objectives

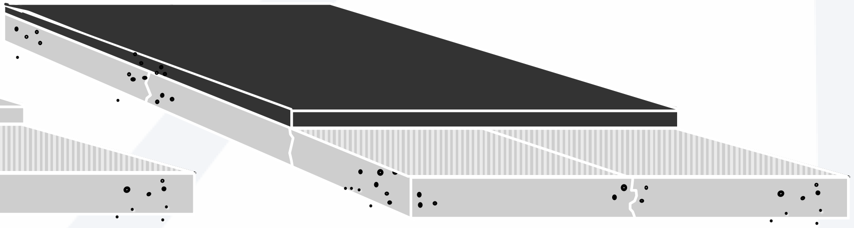
- What is a LCCA?
- Why use the LCCA approach?
- Who is using LCCA?
- What is Federal policy?
- Overview of 5-step LCCA process
- **Important factors and considerations**
- NC's use of LCCA

Background

- When evaluating competing project designs, engineers are often confronted with the option of using alternative materials with wide ranges of design or useful life!



Concrete Overlay



Asphalt Overlay

(Graphic: CP Tech Center)

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?

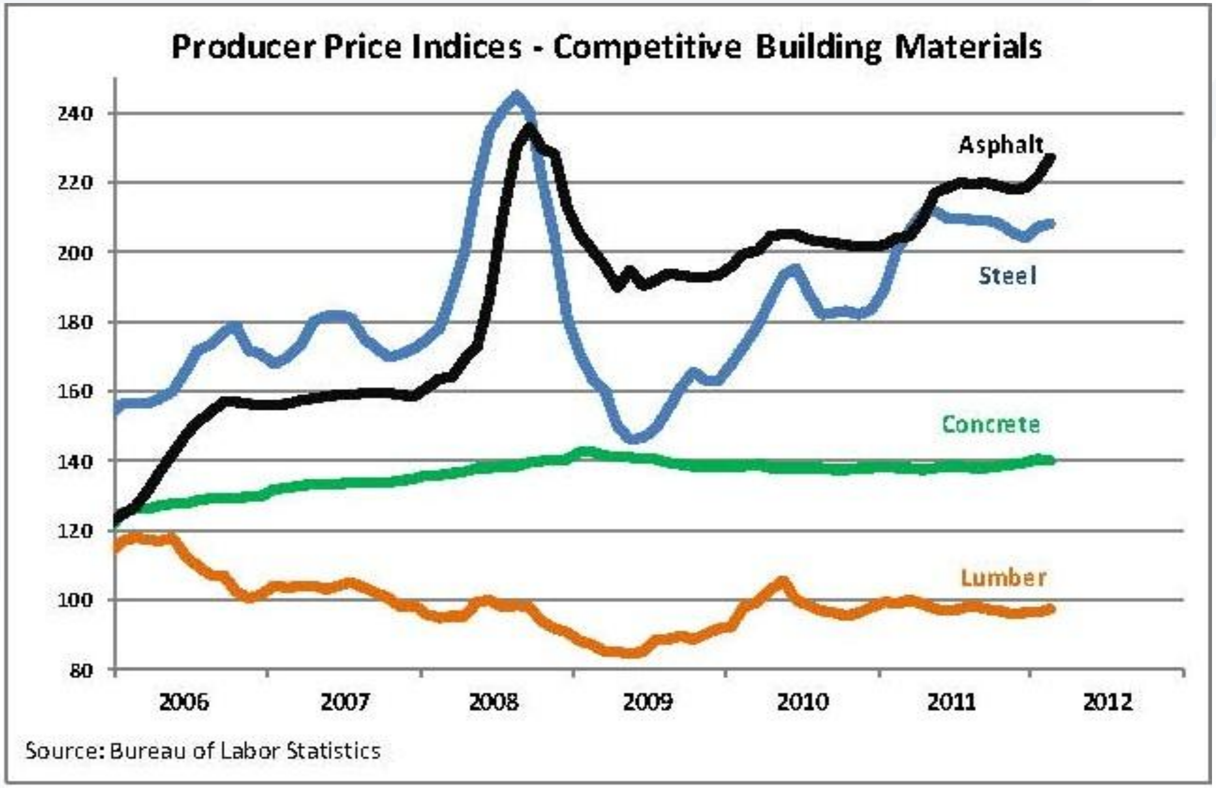
- In short, LCCA is the process of determining the ownership cost of any roadway segment over a prescribed number of years…..asphalt or concrete.

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…



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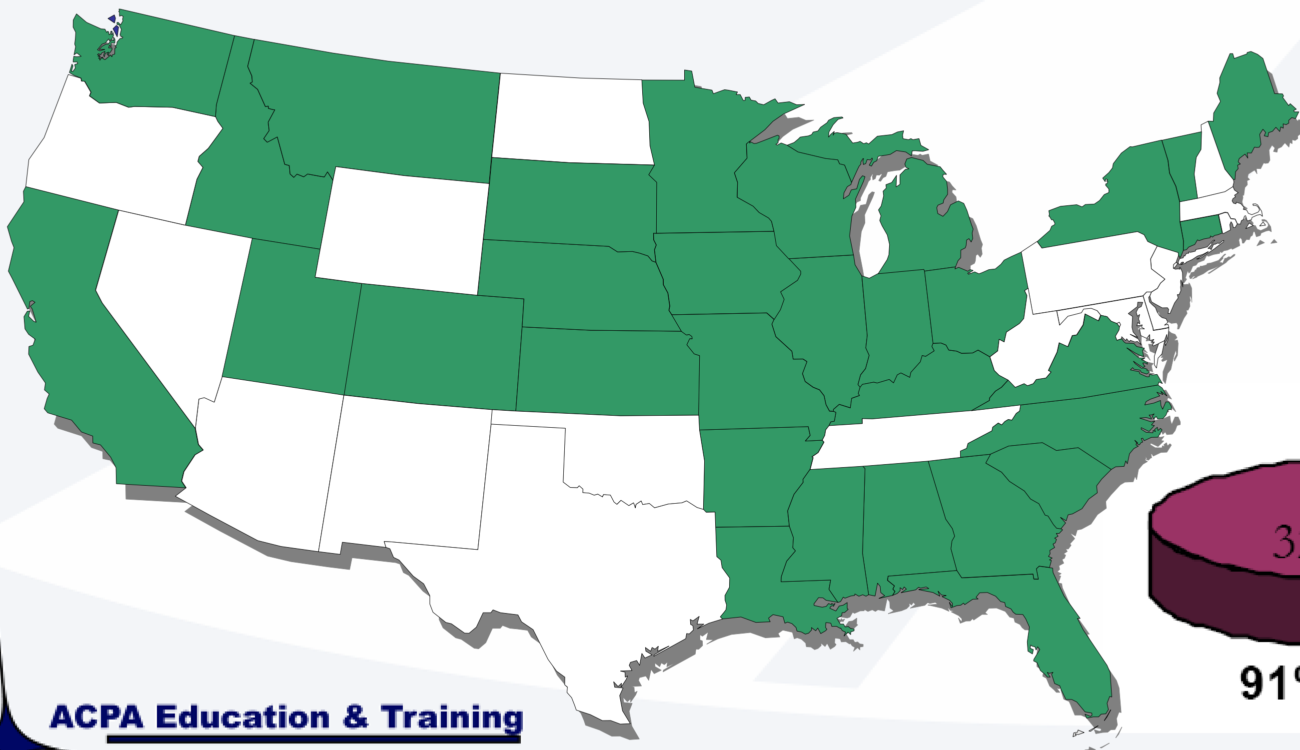
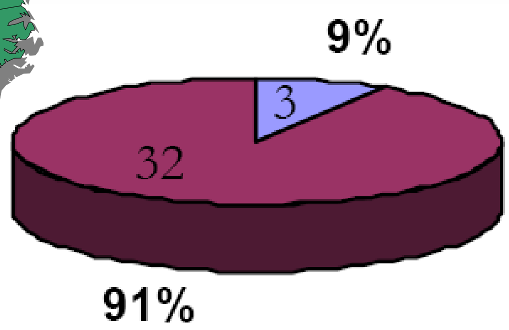
(Source: US BLS)

Who is using LCCA?

- South Carolina DOT SPR 656 – Preliminary
  - 33 states and 2 provinces responded...





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What is FHWA POLICY?

FHWA does not require the use of LCCA, but recommends it's use as a matter of

"GOOD Practice"

Life Cycle Cost Analysis

THE PROCESS *

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The LCCA Process…

- Five steps…

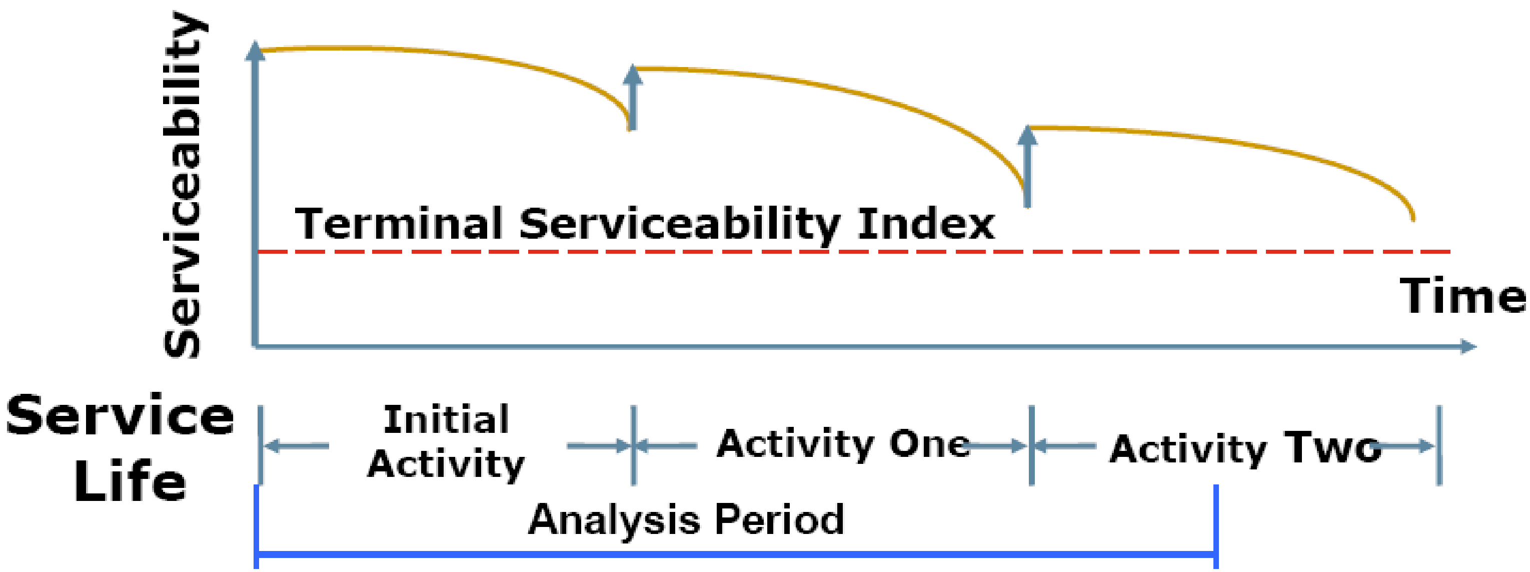
1. Establish design alternatives
2. Determine timing of activities
3. Estimate agency and user costs
4. Compute life-cycle costs
5. Analyze results

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:

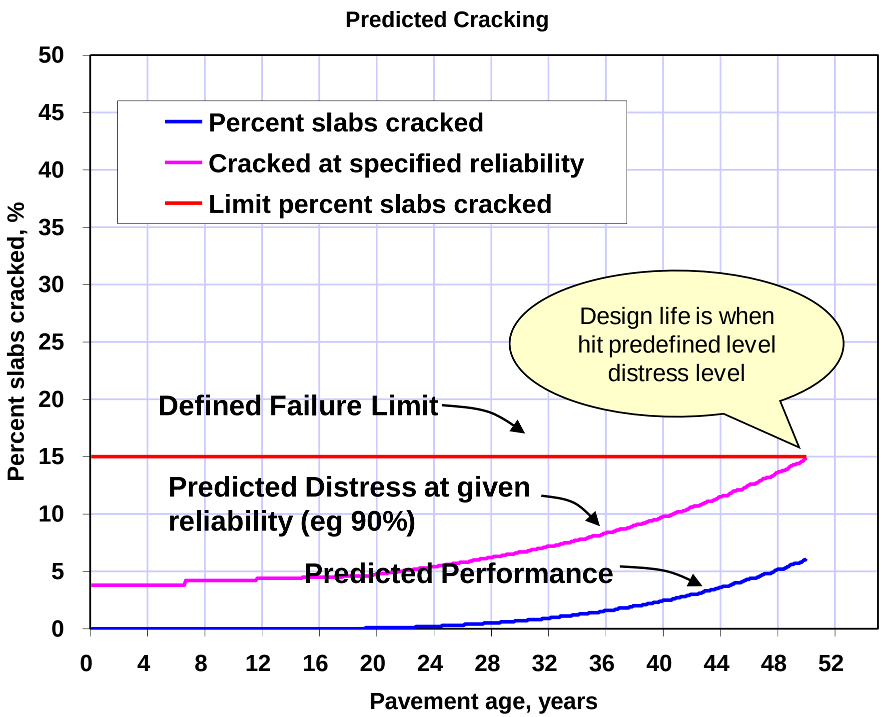
- **Traffic**
- **Climate**
- **Materials**
- **Proposed structure (layer thicknesses and features)**

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



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

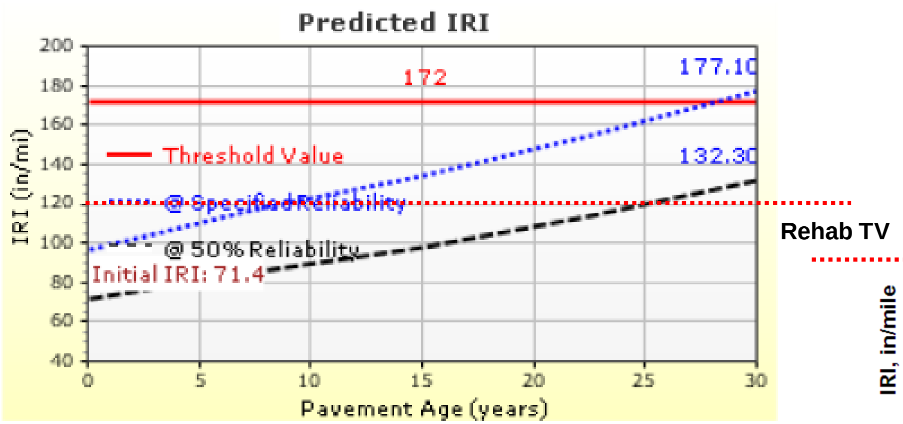
Magenta Line – The level of distresses at the given reliability level (i.e. 90%)

Red Line - <u>Defined Failure Limit</u>. 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)

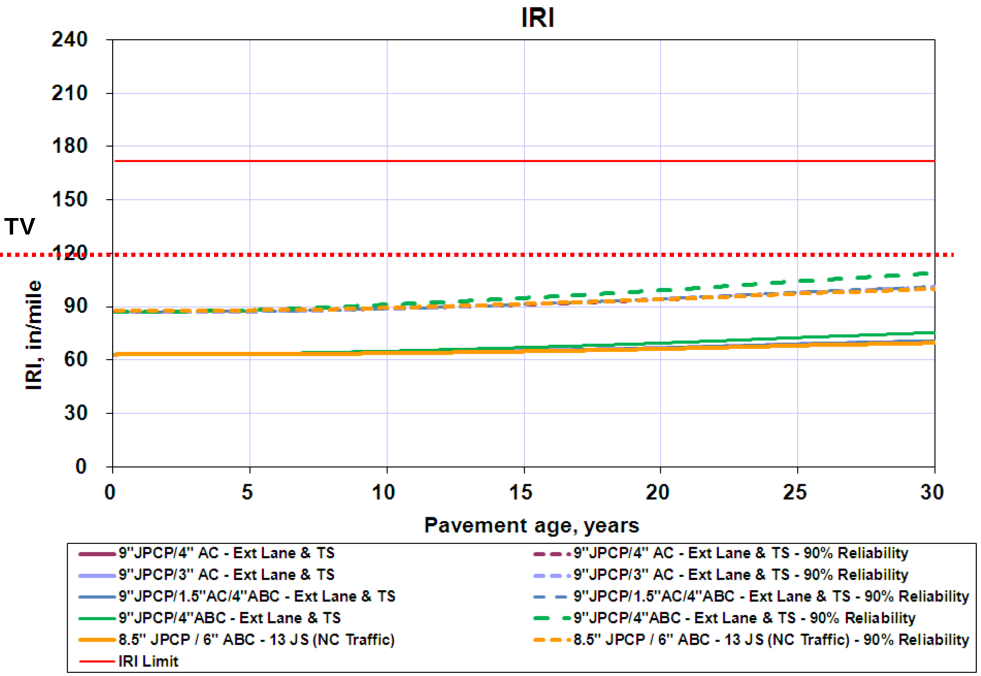
Asphalt Design (From NCDOT)



9" AC / 8" ABC / Subgrade

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

Concrete Designs



No structural repair required
(in line with NCDOT LCCA practices)

	Estimated Costs	Savings
Asphalt Cost	*$ 24,006,921.20*	*$ 1,928,078.36*
Est. Alternate Designs & Cost		
8.5" JPCP / 6" Granular Base	$ 21,008,822.94	$ 4,926,176.61
9" JPCP / 6" Granular Base	$ 21,334,588.71	$ 4,600,410.85
9" JPCP / 1.5 AC/ 4" Granular Base	$ 23,205,188.53	$ 2,729,811.03
9" JPCP / 3" AC	$ 23,912,222.31	$ 2,022,777.25
9" JPCP / 4" AC	**$ 25,934,999.56**	

LCCA: Five-Step Process

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)

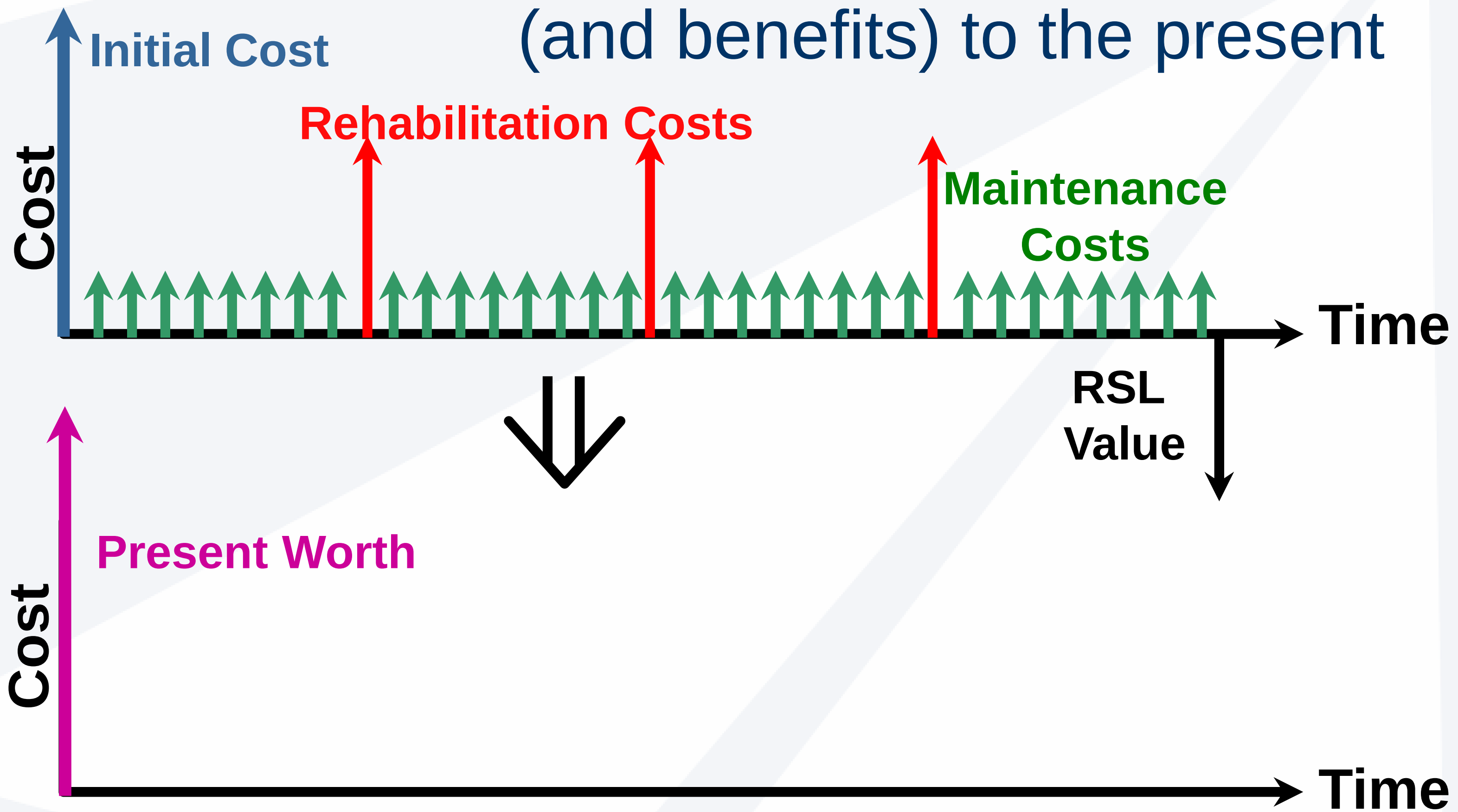
$$\text{Present Worth of Costs} = \sum_{k=0}^{N}\left[(\text{Cost}_k) \times \left[\frac{1}{(1+d)^{n_k}}\right]\right]$$

The bracket $\left[\frac{1}{(1+d)^{n_k}}\right]$ = Present Worth Factor

N = length of analysis period
d = discount rate
n_k = year of expenditure

LCCA – Present Worth Analysis!

Discounts all future costs (and benefits) to the present



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LCCA: Five-Step Process

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

Resources

- In addition several other sources were extremely helpful, including:
  - *Life-Cycle Cost Analysis in Pavement Design*, FHWA SA-98-079 (1998)
  - *Life-Cycle Cost Analysis Revisited*, M. B. Snyder, Ph.D., P.E. (2007)
  - *Avoiding the Pitfalls of Life-Cycle Costs Analysis*, Washington Economic Research Consultants (1987)
  - *RealCost* 2.2, FHWA (2004)

Historic usage of LCCA in North Carolina

LCCA Usage by NCDOT

- "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.

NCDOT Roadway Statistics

- NC has nations 2nd 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

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Does Life Cycle Work for Maintenance?

LCCA Maintenance Options

Asphalt Method

Overlay with Nova chip Asphalt

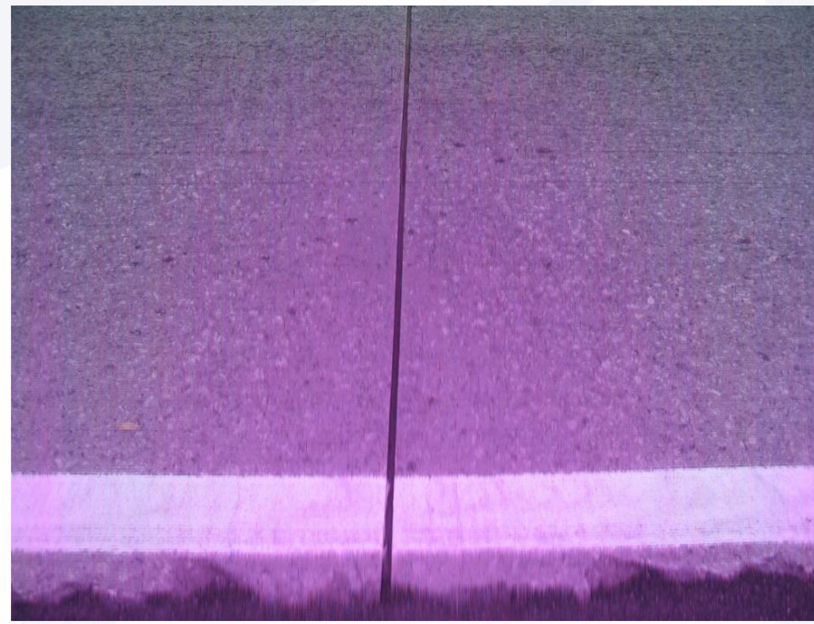
- Mill and Re-overlay in 8-years
- Mill and Re-overlay in 16-years
- Mill and Re-overlay in 24-years

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

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Standing the test of time…….

Hwy 32 – Chowan Co
80-years old

What effect does Life Cycle Cost Analysis & Competition have on bid pricing?

$$$

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The Missouri and Louisiana Experience LCCA and Competition

Missouri

- Number of bids/job increased from 3.7 (2005) to 5.5 (2009)
- Paving Prices Decreased
  - Asphalt Decreased 5.1%
  - Concrete Decreased 8.8%

Louisiana

- Number of bids/job increased from 2.6 to 3.9 (post-Katrina)
- Engineer's Estimate vs. Bid
  - Alternate bids – 9% below est.
  - Non-alternate – 20% above est.
  - In 2008, LA saved $62.5-million
  - Cost to Benefit Ratio of Money Saved vs. Additional Engr. Cost was 1000:1

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???

Jerry W. Reece
Executive Director
NC Concrete Pavement Assn
Jreece@pavementse.com
336-508-5921

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