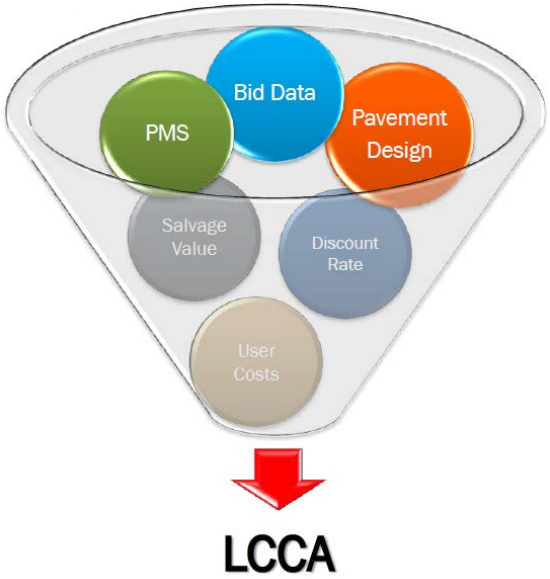
Life Cycle Cost Analysis: A Tool for Better Pavement Investment and Engineering Decisions



Municipal Streets Seminar
November 12, 2014
Ames, Iowa

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John Donahue, P.E. – Missouri DOT

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, restoration, resurfacing, rehabilitation, reconstruction,** and **user** costs, over the life of the project segment.

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Source: Transportation Equity Act for the 21st Century

LCCA Characteristics

- Applied to a project that will be built.
- Analyzes competing strategies.
- Requires equivalent benefits over the same performance period.

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LCCA Characteristics

- Converts future costs to present worth value using discounting.
- Compares only differential costs.
- Determines lowest cost strategy to meet the performance objectives of the project.

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What LCCA is NOT

- A cost/benefit analysis
- A life cycle assessment (carbon footprint analysis)
- Complicated (although can have varying level of detail)
- A decision in and of itself

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What LCCA is NOT

- Advantageous to one industry over another
- Materials specific
- Required for selecting pavements on projects using Federal-aid funds

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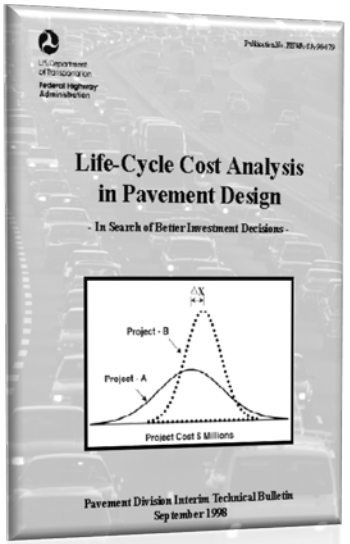
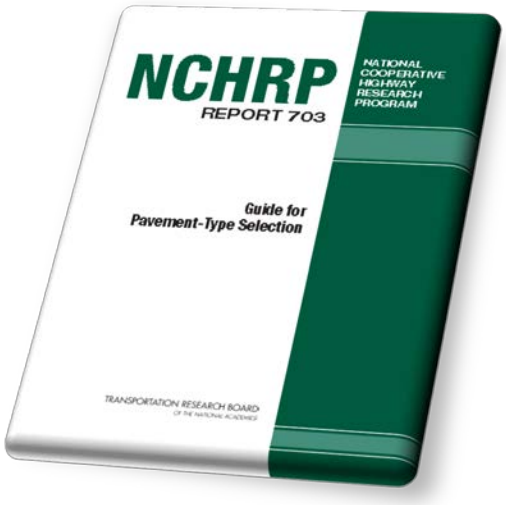
LCCA Documents

- 1998 FHWA Interim Tech Bulletin





- NCHRP 2011 Pavement Type Selection

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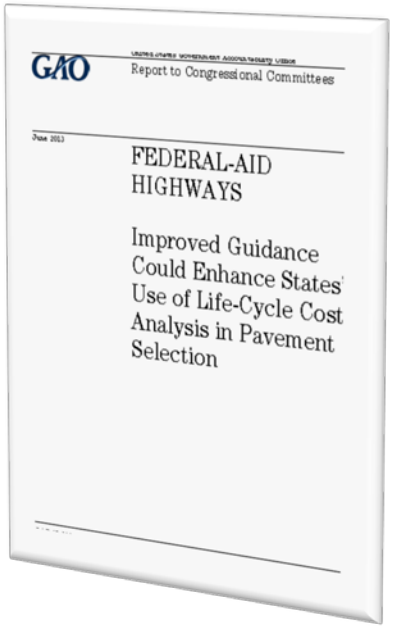
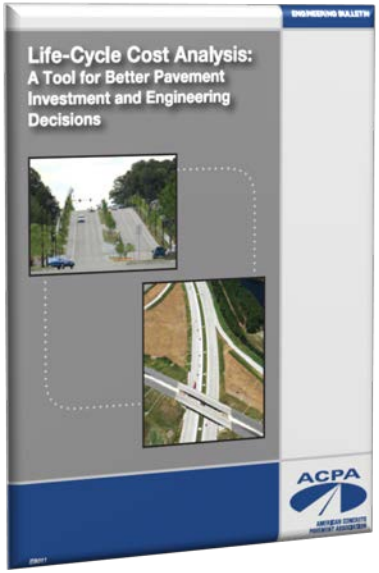
LCCA Documents

- 2013 GAO Report to Congress





- Life Cycle Cost Analysis: A Tool for Better Pavement Investment and Engineering Decisions (ACPA)

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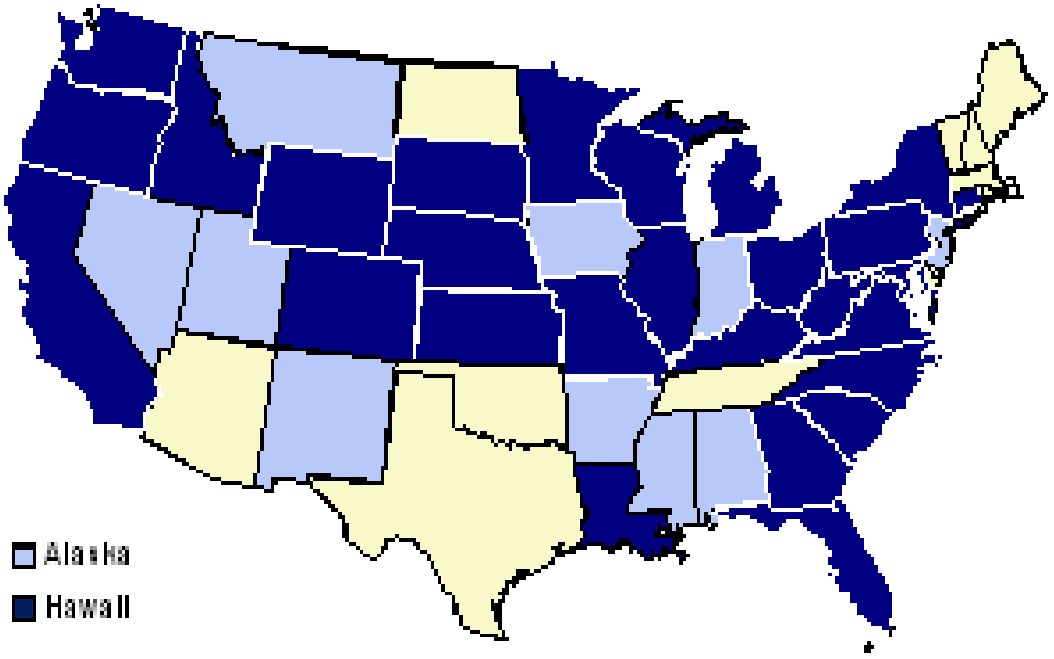
FORTY (40) STATES USE LCCA IN SOME FORM FOR PAVEMENT TYPE SELECTION[1,2,3,4,5]



Legislatively mandated: MI, IL, MN…

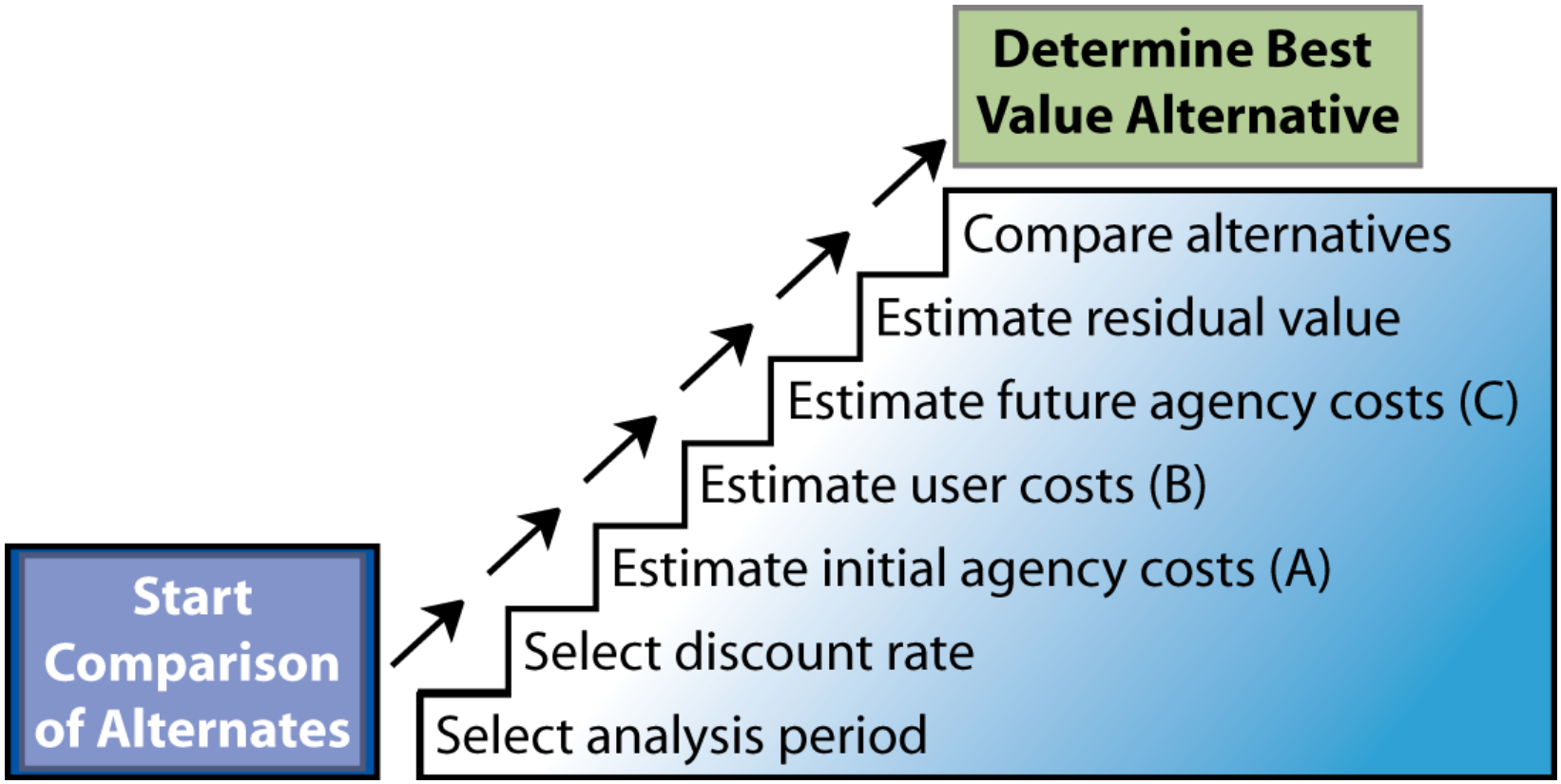
Why use the LCCA approach?

- Make better transportation investment decisions
  - Lowest initial cost may not be most cost effective
  - Accounts for future inflation and time-value of money
- 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
- However, it is important understand LCCA is not a decision in and of itself
  - (it is a decision support tool)

[Mack 2014]

1. 2007 National LCCA Survey by Mississippi DOT
2. National LCCA Survey Conducted by South Carolina DOT
3. State DOT Pavement Design and/or Pavement Type Selection Manuals
4. Survey of American Concrete Pavement Association Chapter Executives
5. Performance Assumptions Used to Support LCCA - State Reports - Fall 2013 NCC Meeting

Basic Steps in a Single Project LCCA



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Step 1- Analysis Period

- The Analysis Period is the length of time (years) for which competing options are evaluated in an LCCA
- FHWA guidance: “Analysis Periods used in LCCA should be long enough to capture long term differences in discounted life-cycle costs among competing alternatives.”
- The period should be long enough to include all of the major costs each option will incur over a long period of time.

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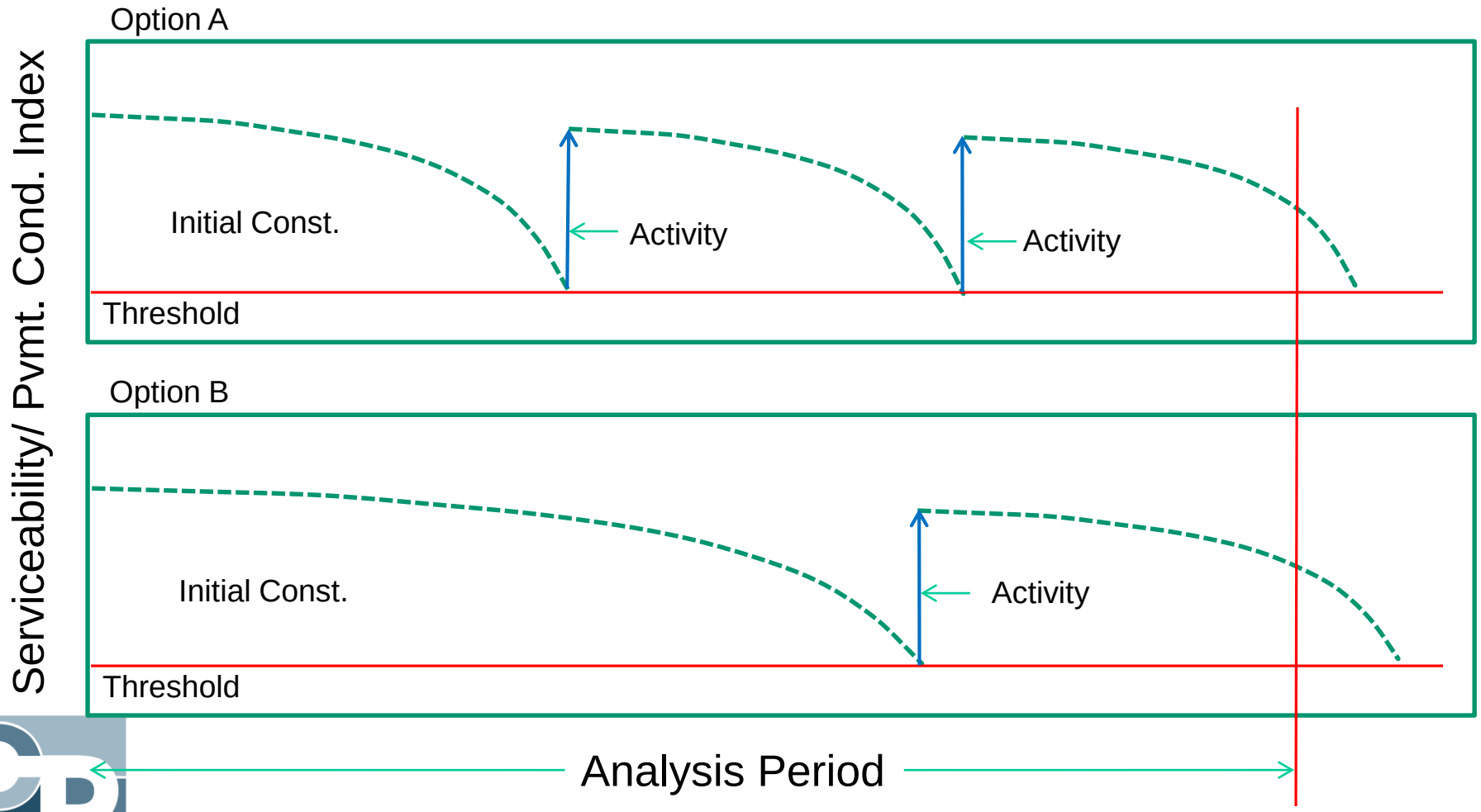
Analysis Period



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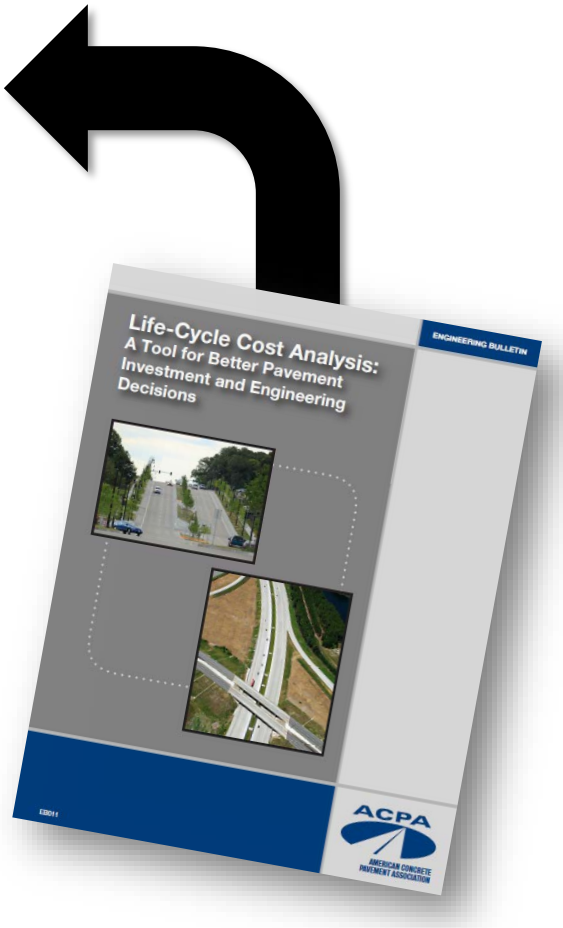
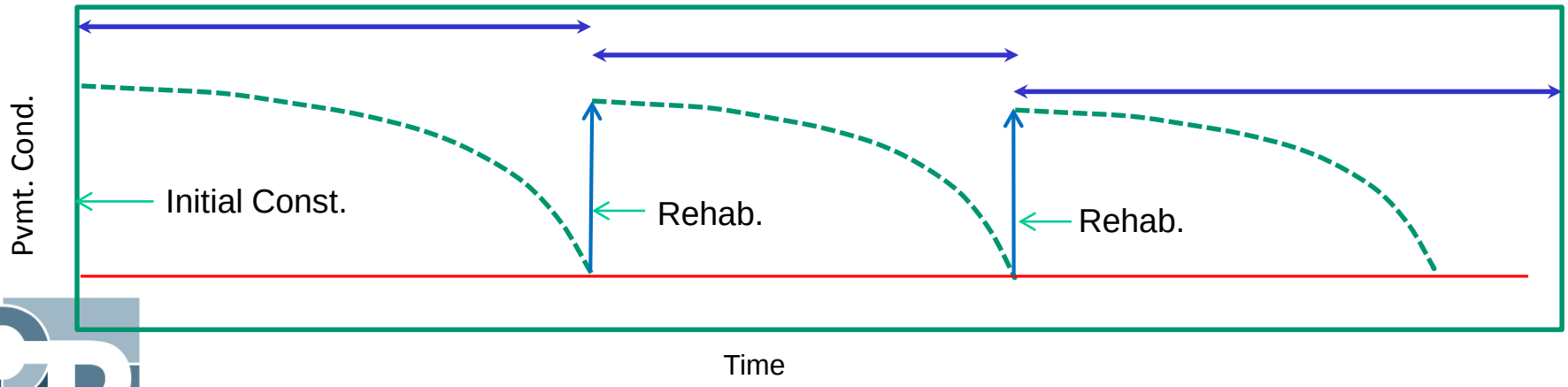
Agency Practices

Analysis Period (yrs)	Percent of Responding Agencies	State Agency
< 30	4%	AL
30	11%	NC, SC, WY
35	18%	AK, AR, ID, MT, OH
40	**39%**	CO, FL, GA, IA, IN, KS, KY, LA, MD, MS, SD
45	7%	IL, MO
50+	21%	MN, NE, NY, VA, WA, WI



Performance Period

- A Performance Period, also known as a Service Life, is the expected time (in years) between the pavement construction and rehabilitation activities.
- In practice, subsequent performance periods between rehabilitation treatments usually become shorter because of increased traffic and damage.



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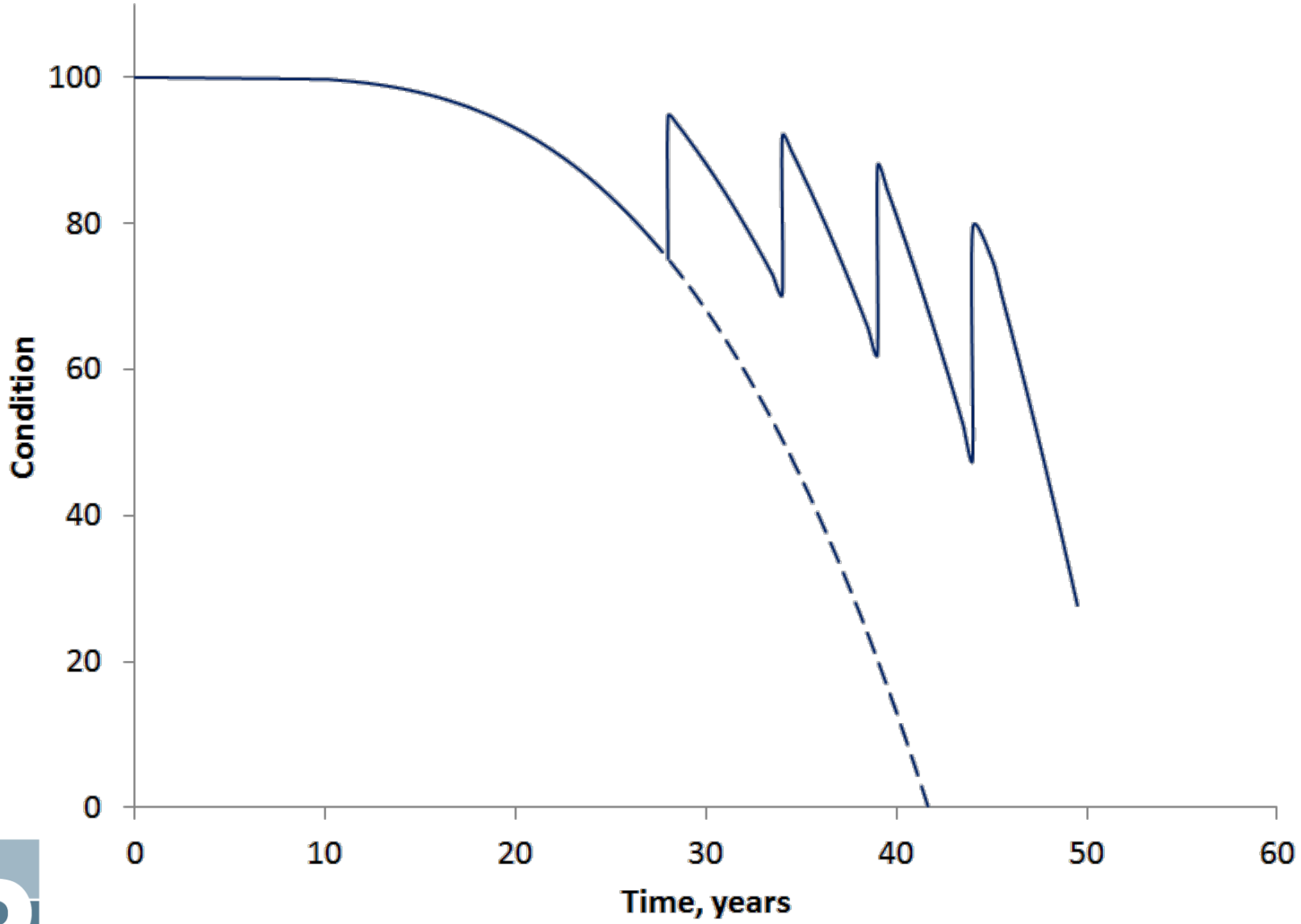

Source: ACI Seminar on Performance-Specification for Concrete, Tom Yu, Federal Highway Administration, National Concrete Consortium (NCC) Meeting, Jacksonville FL, April 24, 2014

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LCCA Pavement Treatments

- Pavement Preservation:
  1. preventive maintenance,
  2. minor rehabilitation (non-structural)
  3. some routine maintenance activities

- Pavement Rehabilitation:
  1. structural overlays
  2. restoration treatments

- Pavement Reconstruction:
  1. replacement of the existing pavement structure

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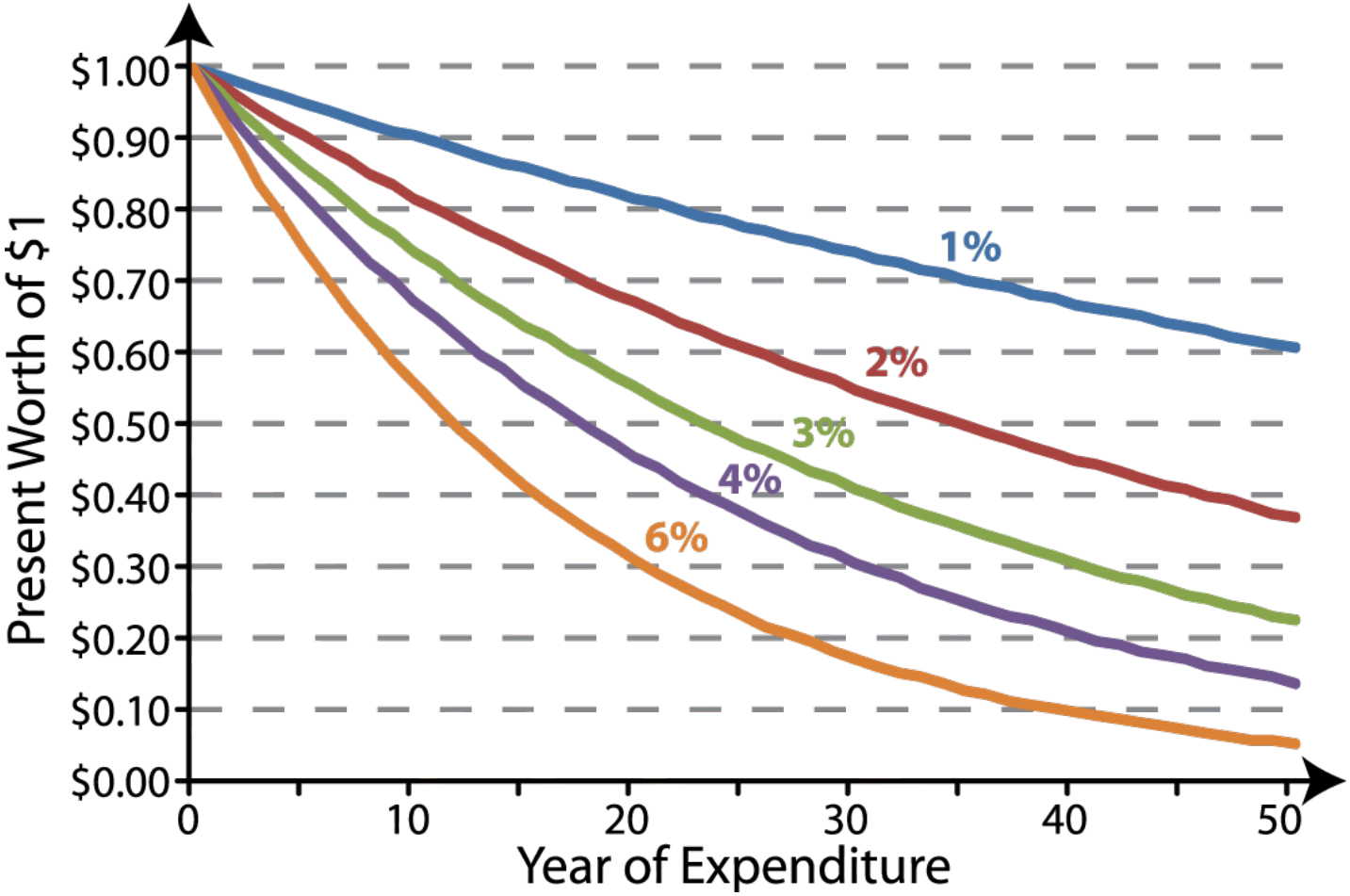
Step 2 – Select a Discount Rate



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LCCA Discount Rate

- The **real discount rate** (also known as the real interest rate) is used in pavement LCCAs.
  - Accounts for fluctuations in both investment **interest rates** and the **rate of inflation**.
  - Discount rate = Interest rate – Inflation rate.
  - Today's costs can be used as proxies for future costs.

$$d = \frac{1 + i_{int}}{1 + i_{inf}} - 1$$

d = the real discount rate, %
i_{int} = the interest rate, %
i_{inf} = the inflation rate, %

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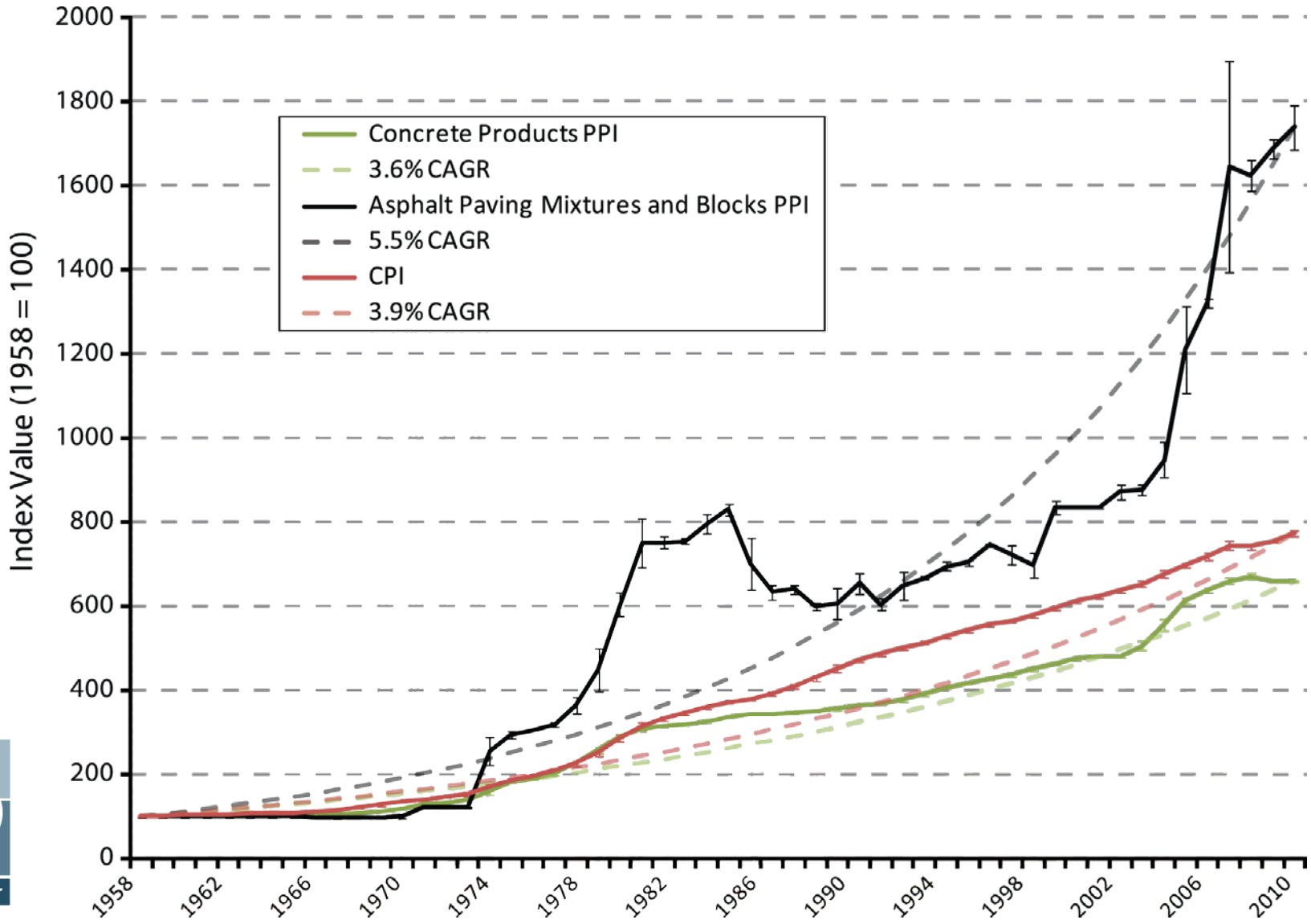
Historical Inflation Rates



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Accounting for Material Inflation

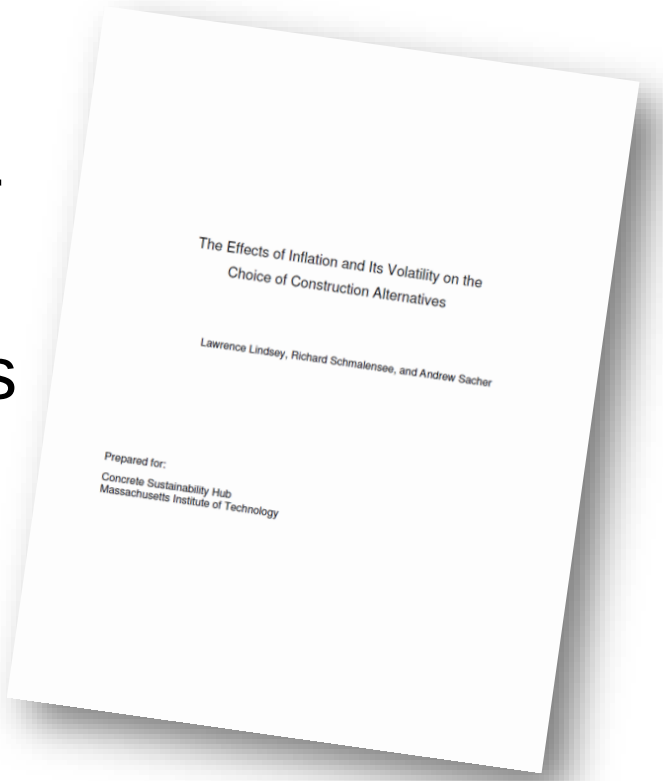
- **Material-specific real discount rates**

  or

- **Escalating the future value** of an item before calculating its present or annual worth.
  - MIT has proposed **"real price" escalators** that are dependent on the year in the LCCA in which the activity is conducted.

MIT Real Price Escalators

- Used previous price indices for concrete, asphalt, steel and lumber + Monte Carlo analyses to provide a means of accounting for material price inflation and volatility in an LCCA framework



The Effects of Inflation and Its Volatility on the Choice of Construction Alternatives

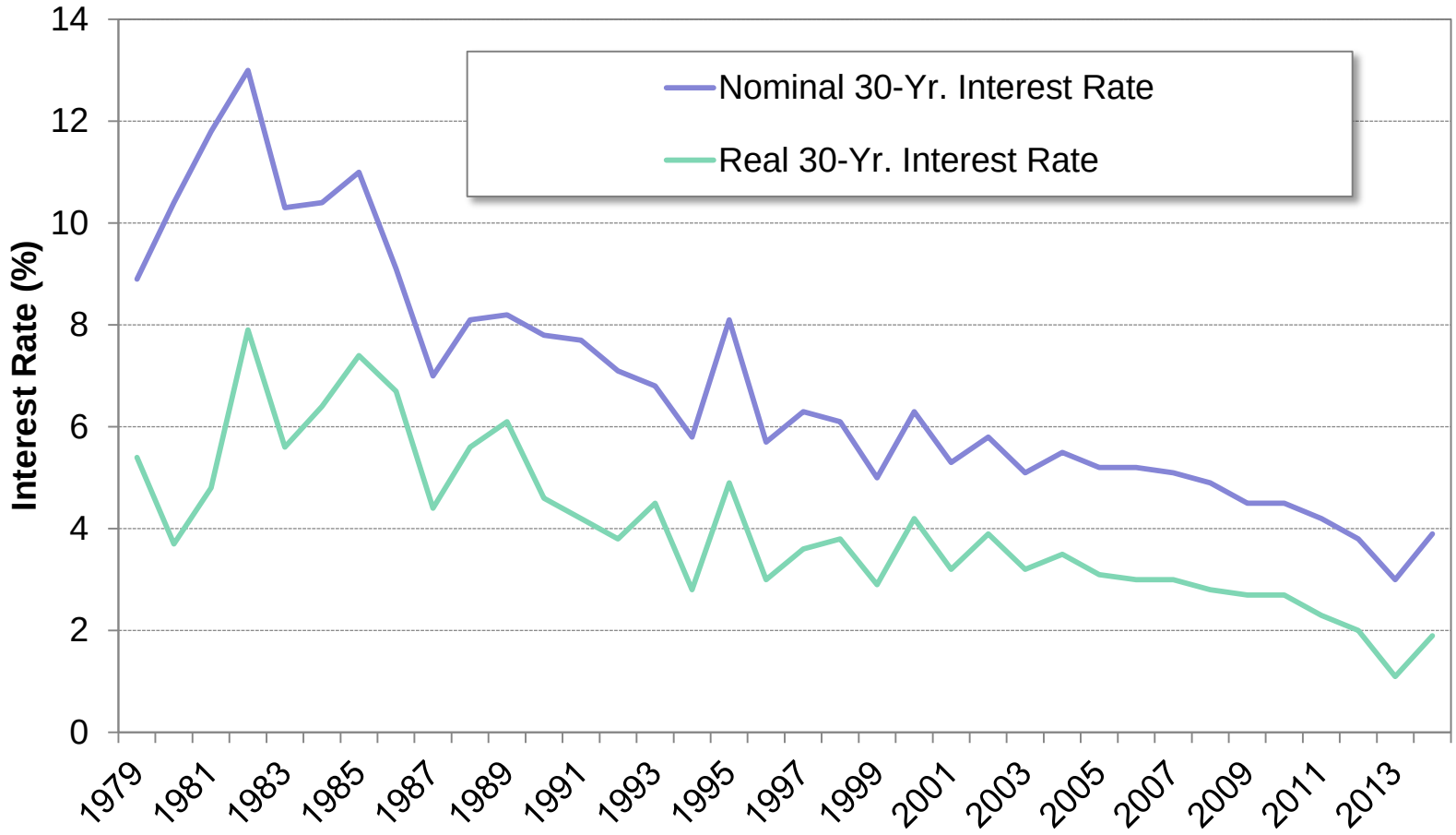
Lawrence Lindsey, Richard Schmalensee, and Andrew Sacher

Prepared for:
Concrete Sustainability Hub
Massachusetts Institute of Technology

	Year	Mean	Percentiles								
			10	20	30	40	50	60	70	80	90
Conc.	10	-0.49%	-1.59%	-1.21%	-0.93%	-0.71%	-0.48%	-0.30%	-0.06%	0.20%	0.57%
	20	-0.49%	-1.26%	-1.00%	-0.81%	-0.65%	-0.47%	-0.33%	-0.18%	-0.01%	0.28%
	30	-0.49%	-1.11%	-0.93%	-0.76%	-0.62%	-0.49%	-0.37%	-0.24%	-0.05%	0.15%
Asph.	10	1.15%	-1.14%	-0.53%	-0.05%	0.37%	0.87%	1.34%	1.95%	2.63%	3.84%
	20	1.14%	-0.57%	-0.07%	0.30%	0.60%	0.96%	1.38%	1.77%	2.22%	2.93%
	30	1.14%	-0.32%	0.13%	0.42%	0.75%	1.02%	1.34%	1.68%	2.05%	2.69%

Historical Interest Rates

OMB Circular A94 Appendix C



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Calculating the Real Discount Rate

- If local interest and inflation rates are not readily available to develop a local real discount rate, ACPA supports the use of the United State's Office of Management and Budget (OMB) real discount rate.

- If there is concern with the variability in the OMB real discount rate, a moving average of the value should be considered.

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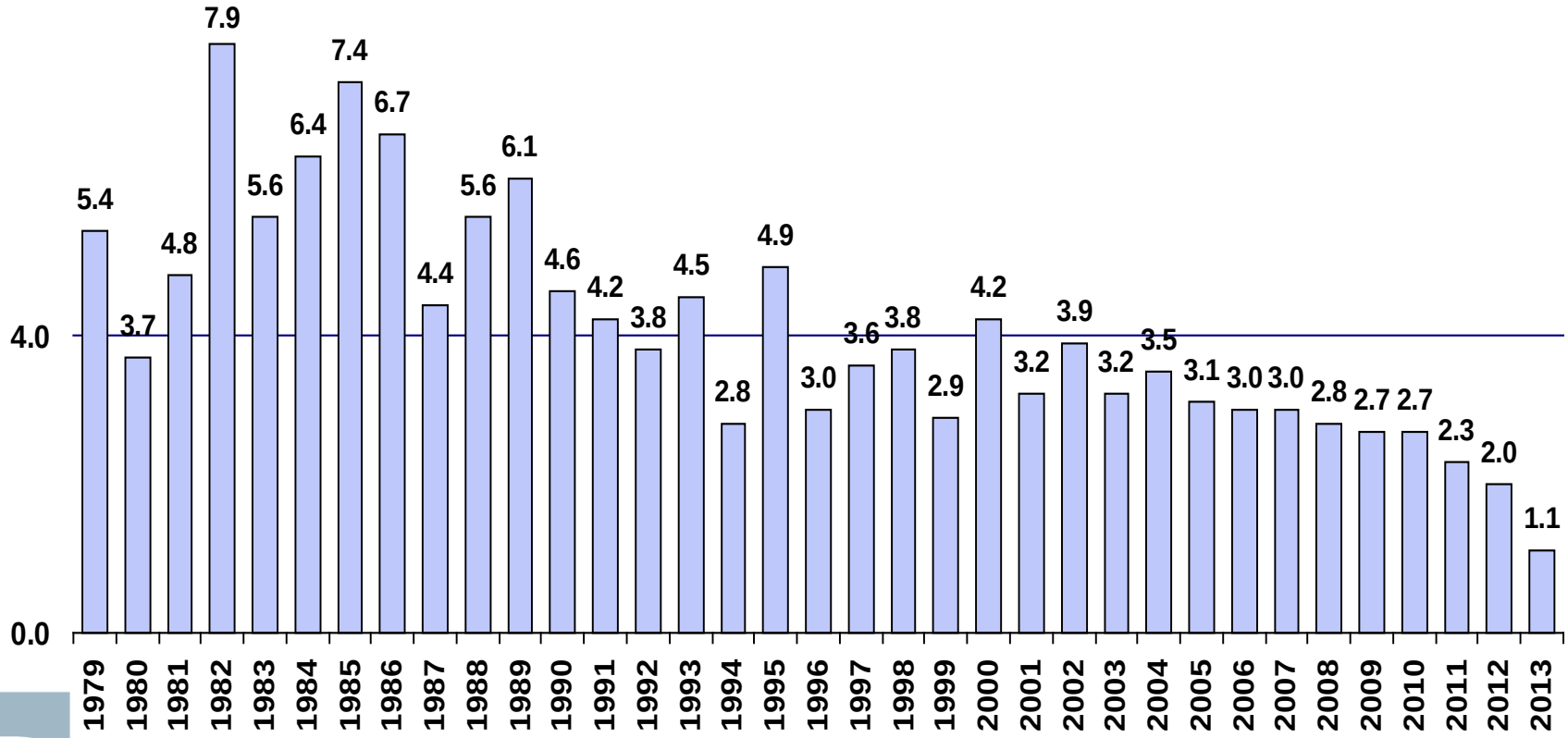
OMB DISCOUNT RATES

Circular A94 Appendix C



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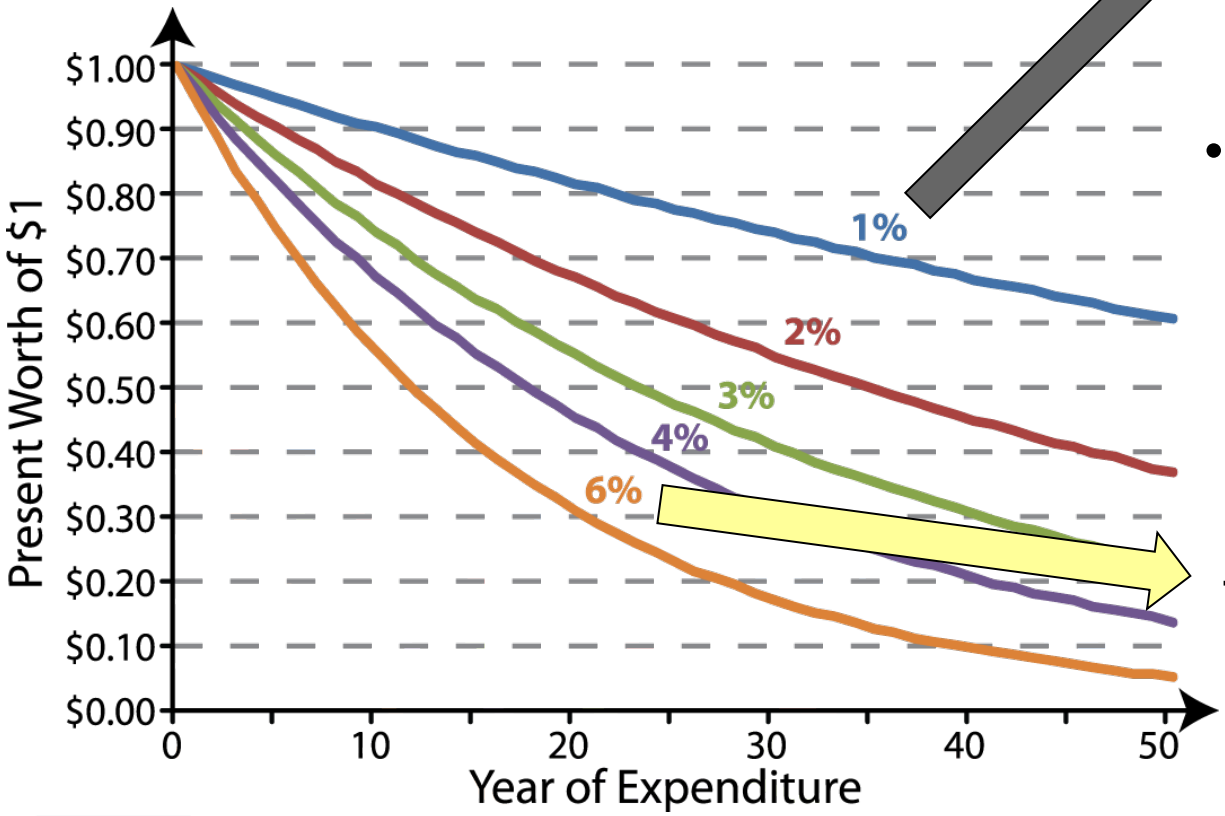
High vs Low Discount Rate



Low Discount Rate

- Present worth of future expenditure is closer to current cost
- Favors high initial cost and low future cost options

High Discount Rate

- Present worth of future expenditure is greatly reduced
- Favors low initial cost and high future cost options

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Agency Practices: Discount Rate

Real Discount Rate (%)	Percent of Responding Agencies	State Agency
< 3	18%	MI*, MN*, MO*, NV*, OH*, SC*, WV*
3	15%	GA, IA, IL, KS, MD, MT
3 to 4	10%	AR, CO*, FL, NE
4	**49%**	AK, AL, CA, CT, DE, ID, IN, LA, MS, NC, NJ, NM, NY, PA, TN, UT, VA, WA, WY
4 to 5	3%	SD
5	5%	KY, WI

* Denotes a state whose real discount rate is based either on the OMB or a moving average of the OMB.

OMB Circular A-94, App. C	
2014	1.9%
2013	1.1%
5-yr avg	2.0%

Step 3 – Estimate Initial Agency Costs

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Initial Agency Costs

- Only those **initial agency costs that are different** among the various alternatives need to be considered for reasonably similar alternates.
- **Pavement costs** include items such as subgrade preparation; base, subbase, and surface material; associated labor and equipment; etc.
- **When historical bid prices are used as estimates**, consider the impact of material price escalators, payment practices, and bidding practices.

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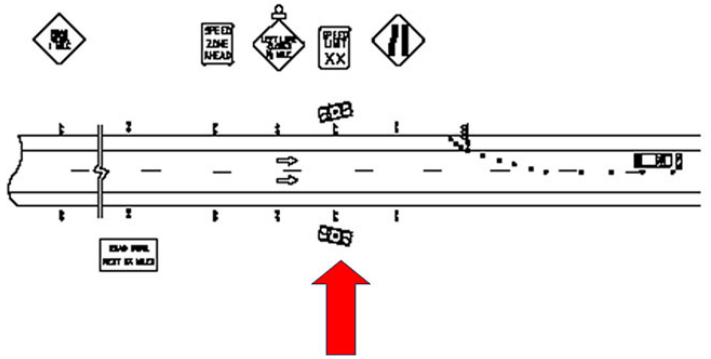

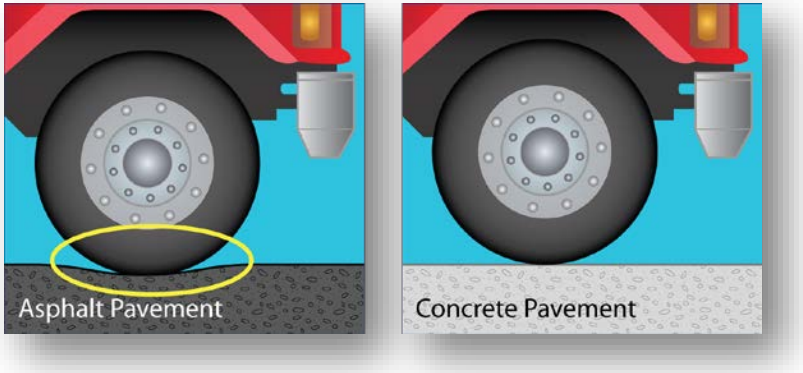

Step 4 – Estimate User Costs

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User Costs

- Costs that are incurred by **users of the roadway** over the analysis period.
  - **Work zone costs:** Incurred during lane closures and other periods of construction, preservation/rehabilitation, and maintenance work.
  - **Vehicle operating costs:** Incurred during the normal use of the roadway.
  - **Delays due to capacity issues:** Primarily a function of demand for use of the roadway with respect to roadway capacity (not likely to vary between alternates).
  - **Accidents:** Damage to the user's/other's vehicle and/or public or private property; injury costs. (not likely to vary between alternates).

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Agency Practices: User Costs

User Costs Considered	Percent of Responding Agencies	State Agency
Yes	42%	AK, AZ, CA, CO, CT, DE, GA, KS, KY, LA, MD, MI, NM, PA, SC, VT, WA
No	**58%**	AL, AR, FL, IA, ID, IL, IN, MN, MO, MS, MT, NC, NE, NJ, NV, NY, OH, SD, TN, UT, WI, WV, WY

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Step 5 – Estimate Future Agency Costs

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Future Agency Costs

- **All cost components must be considered** because the present value of costs associated with engineering, administrative, and traffic control are impacted by the time value of money.
- Future activities are dependent on the initial pavement design.
- Must consider both **maintenance/operation** and **preservation/rehabilitation costs** and timing.

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Maintenance/Operation Costs

- **Several billion dollars** are spent each year on pavement maintenance by highway agencies in the U.S.
- Short-term solutions typically have significantly larger maintenance requirements than long-life solutions, regardless of the size of the project.

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Agency Practices: Maint Costs

Maint. Costs Considered	Percent of Responding Agencies	State Agency
Yes	**77%**	AK, AR, CA, CO, DE, GA, ID, IL, IN, KS, LA, MI, MN, MT, NC, NE, NM, NV, PA, TN, UT, VT, WI, WV
No	23%	AL, IA, MD, MO, OH, SC, WA

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Preservation/Rehabilitation Costs

- **Large future agency costs** associated with improving the condition of the pavement or extending its service life.
- Preservation and rehabilitation **activities and their timing** should be based on the distresses that are predicted to develop in the pavement.
- Best to develop pavement performance predictions based **on local performance history data**; otherwise, Pavement ME can be used.

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Agency Practices: Rehab Costs

Rehab. Costs Considered	Percent of Responding Agencies	State Agency
Yes	**97%**	AK, AL, AR, CA, CO, DE, GA, IA, ID, IL, IN, KS, LA, MD, MN, MO, MS, NC, NE, NM, NV, OH, PA, SC, TN, UT, VT, WA, WI, WV
No	3%	MI

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Step 6 – Estimate Residual *or* Salvage Value

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Residual *or* Salvage Value

- Defined in **one** of three ways:
  - The net value that the pavement would have in the marketplace if it is **recycled at the end of its life**,
  - The value of the **remaining service life (RSL)** at the end of the analysis, *OR*
  - The value of the existing pavement as a **support layer for an overlay** at the end of the analysis period.
- Residual *or* salvage value **must be defined the same way** for all alternatives.
- Always in final year, so Δ$ is what is important.

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...Think about Your Last Car

At the end of your ownership it was either

OR

Traded in or sold to a private party because it could continue to be used.

Sold for scrap value because it was not drivable due to age or accident.

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Agency Practices: Residual Value

Residual Value Considered	Percent of Responding Agencies	State Agency
Yes	**51%**	AK, AR, CA, CO, CT, GA, HI, ID, IN, KS, MD, MN, NE, NV, NY, VA, WI , WA
No	49%	AL, FL, IA, IL, KY, LA, MI, MO, MS, NC, OH, SC, SD, TN, UT, WV, WY

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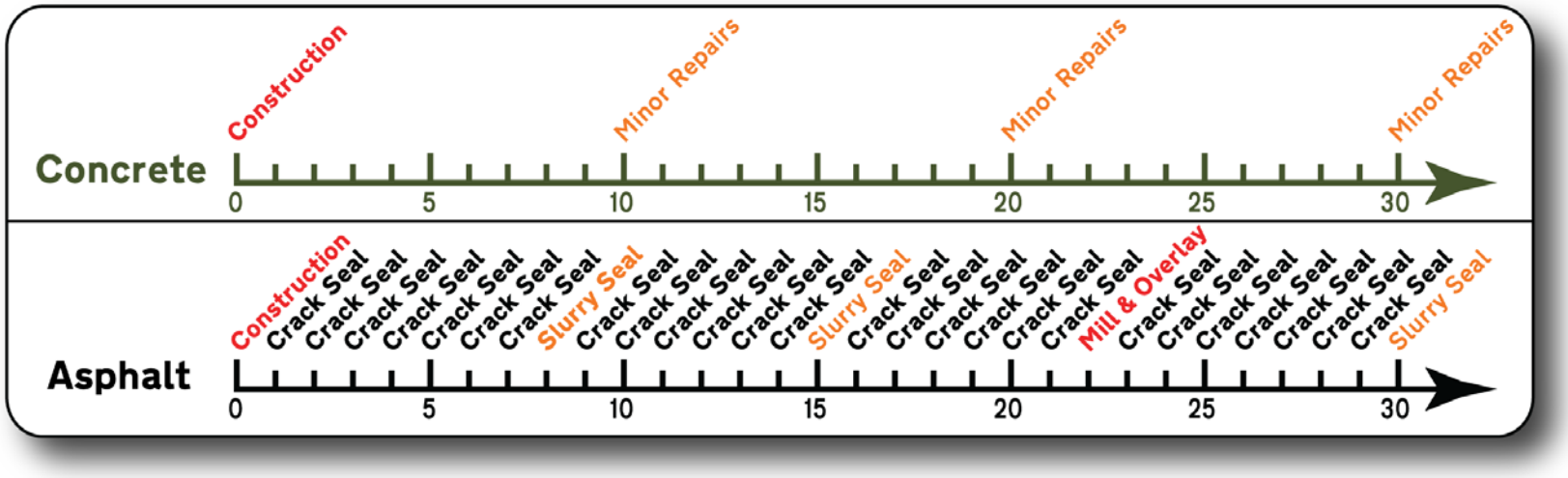

Pavement Management Plan from City of Leawood, Kansas

Step 7 – Compare Alternatives

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Compare Alternatives

- Alternatives considered must be compared using a **common measure of economic worth**.
- Investment alternatives such as pavement strategies are most commonly compared on the basis of:
  - Present worth (also called net present value [**NPV**])
  - Annual worth (also called equivalent uniform annual cost [**EUAC**])
- NPV and EUAC provide the same ranking

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Net Present Value (NPV)

- NPV analyses are directly applicable only to **mutually exclusive alternates** each with the **same analysis period**.
- The formula for the **present value or worth** ($P) of a **one-time future cost or benefit** ($F) is:

$$\$P = \$F \times \left[\frac{1}{(1+\mathrm{d})^{\mathrm{t}}}\right]$$

d = the real discount rate, %
t = the year in which the one-time future cost or benefit occurs

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Agency Practices: Calc Method

Calculation Method Used	Percent of Responding Agencies	State Agency
Net Present Value (NPV) Only	**66%**	AL, AR, AZ, CA, CO, KS, LA, MD, MN, MO, MT, NM, NV, OH, SC, UT, VT, WA, WV
Equivalent Uniform Annual Cost (EUAC) Only	17%	DE, IL, MI, NC, WI
Both NPV and EUAC	17%	GA, ID, IN, PA, TN

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Analysis Methods

- **Deterministic** approach – a single defined value is assumed and used for each activity.
- **Probabilistic** approach – variability of each input is accounted for and used to generate a probability distribution for the calculated life-cycle cost.

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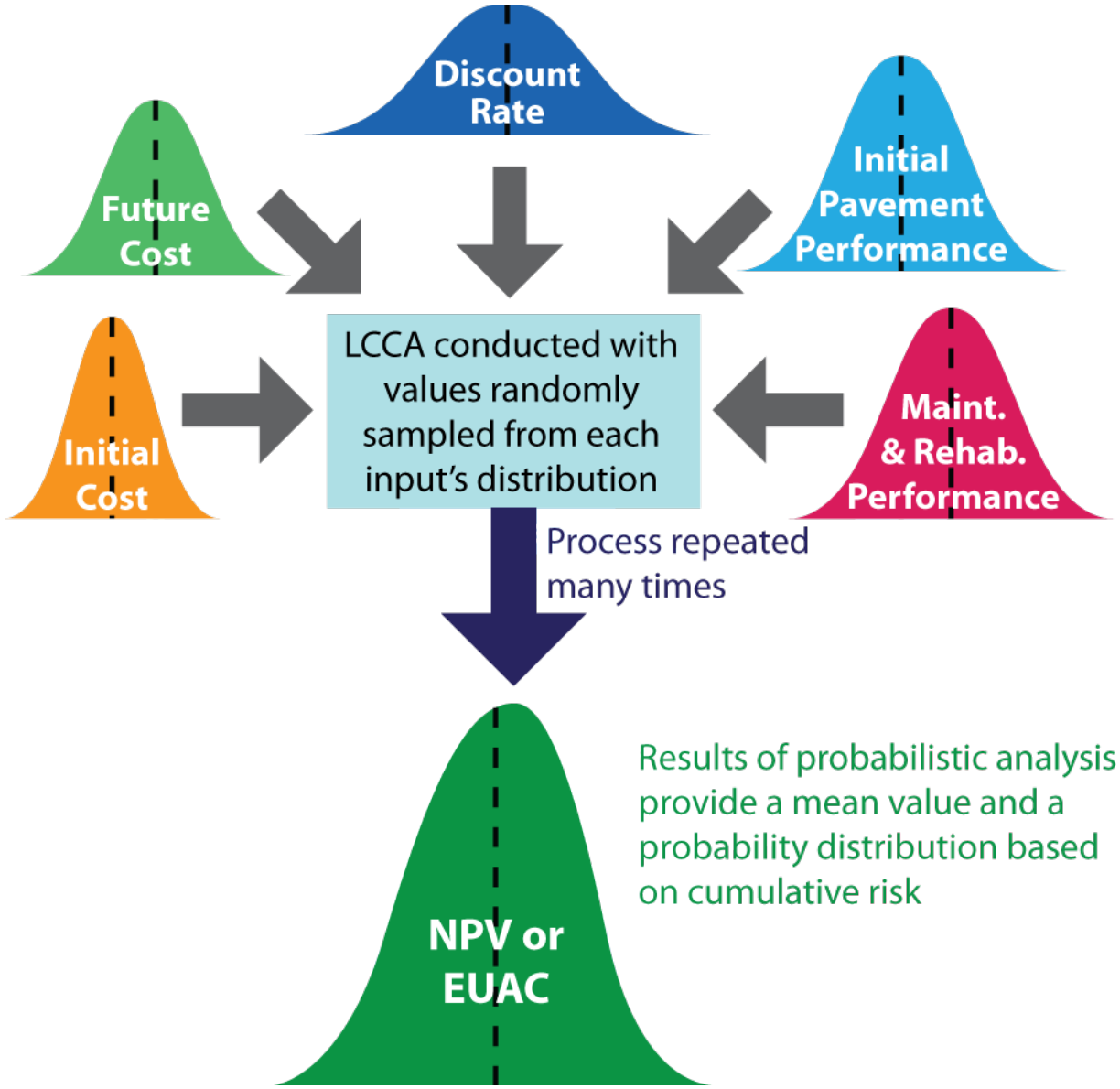
Probabilistic Analysis Method



Results of probabilistic analysis provide a mean value and a probability distribution based on cumulative risk

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Agency Practices: Analysis Method

Analysis Method Used	Percent of Responding Agencies	State Agency
Deterministic	**80%**	AL, AR, AZ, CA, GA, ID, IL, KS, LA, MI, MN, MO, MT, NC, NM, NV, OH, PA, TN, UT, VT, WI, WV
Probabilistic	10%	CO, IN, MD
Both Det. and Prob.	10%	DE, SC, WA

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Analysis Tools

- Most modern **spreadsheet software** include standard functions for calculating the present worth and annual worth.
- **Proprietary software** to compute LCCAs include:
  - AASHTOWare Pavement ME (deterministic)
  - FHWA's RealCost (deterministic and probabilistic)
  - ACPA's StreetPave & WinPAS (both deterministic)
  - CAC's CANPave (deterministic)
  - Asphalt Pavement Alliance's (APA's) LCCA Original and LCCA Express (both deterministic)

Agency Practices: Analysis Tools

LCCA Tool Used	Percent of Responding Agencies	State Agency
State-Developed Tool	**62%**	AR, GA, ID, IL, KS, MI, MN, MO, MT, NC, NM, NV, OH, PA, SC, TN, UT, WI
RealCost	41%	AZ, CA, CO, DE, IN, LA, MD, SC, TN, UT, VT, WA
DARWinME™	17%	AL, CO, TN, VT, WV

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LCCA Bid Adjustment

The difference in the NPV of anticipated future costs should be added to the initial bid price of the alternative with the higher NPV.

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Important LCCA Considerations

1. Analysis Period is an important policy decision that should consider the likelihood that a pavement alternative may have to be completely reconstructed.
2. Excellent Pavement Management System data is the best source of information in setting expected service lives of new pavements and rehabilitations.
3. Great care should be taken when calculating salvage or residual value to include realistic figures.
4. User Costs can have a significant impact on LCCA while including costs that are well outside of the responsibility of the agency.
5. Uncertainty exists for many of the inputs in LCCA. The probabilistic approach to LCCA can take uncertainty into account.

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Example of Single-Project LCCA in Iowa with StreetPave

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Project Level Inputs

Next

Concrete and Asphalt

Project Length	0.45	miles
Lane Width	12.0	feet
Total Number of Lanes	2	
Analysis Period	30	years

Discount Rate

○ Interest Rate	5.00	%	◉ Discount Rate	1.9
Inflation Rate	3.10	%		

Concrete Only

Concrete Surface Thickness	8	in.	Composite Subbase Density*	120
Subbase Thickness	0	in.		

*Note: Only needed if you plan to enter composite subbase costs as $/ton as opposed to $/SY

Asphalt Only

Design Thickness	9	in.	Surface Course Density	145	lb/CF
Amount of Design Thickness Which is Surface Course	3	in.	Base Density	140	lb/CF
Remaining Base Amount	6	in.	Aggregate Base Density*	120	lb / CF
Aggregate Base Thickness	0	in.			

*Note: Only needed if you plan to enter aggregate base costs as $/ton as opposed to $/SY

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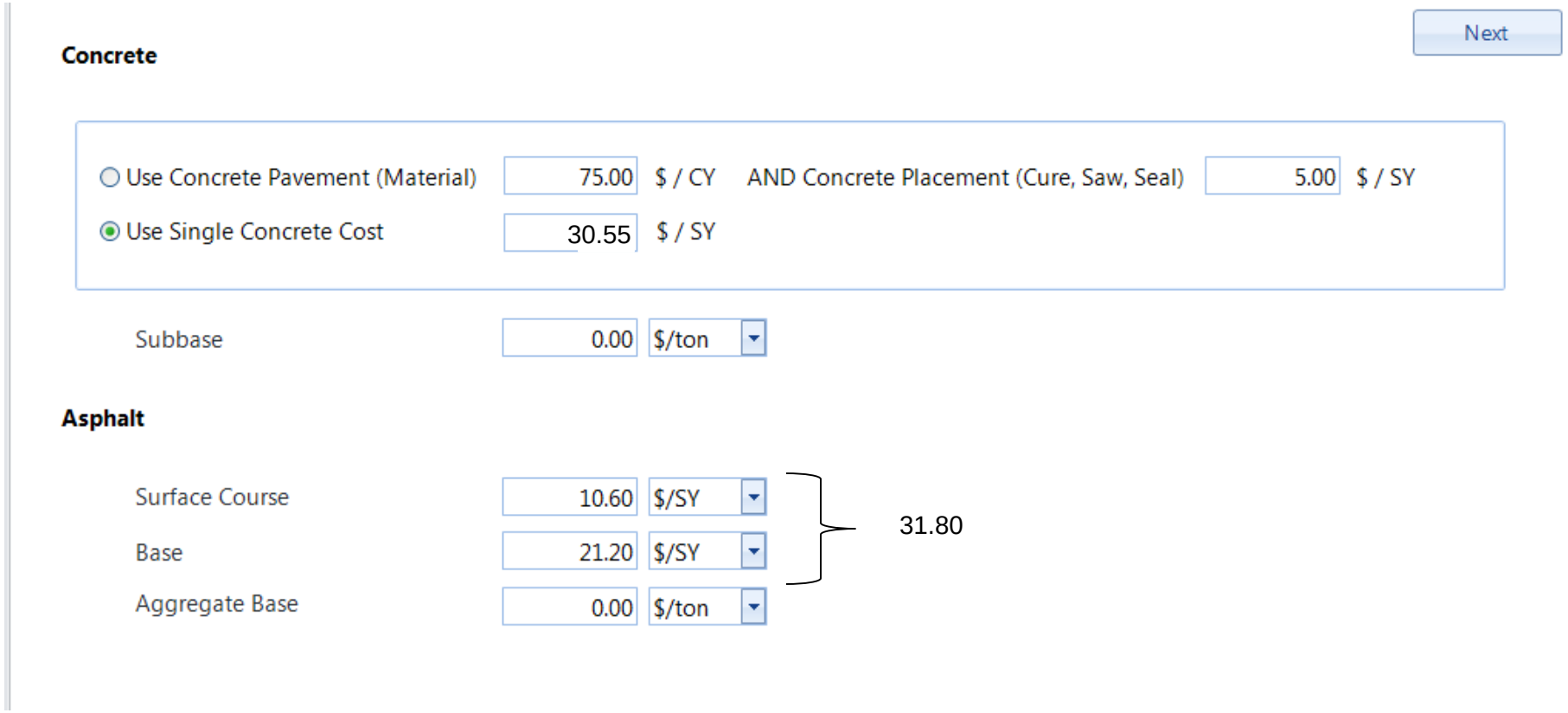
**Remember:

Equivalent designs
Equivalent testing requirements



**Remember:

Equivalent pay items – by the square yard

Maintenance Costs

Concrete Cost Inputs

Concrete Annual Maintenance: $0.00 / SY
Joint Sealant: $0 / lf
Full-Depth Repairs: $90.00 / SY

Partial-Depth Repairs: $150.00 / SY
Diamond Grinding: $5.50 / SY
Hot pour sealant and single sawcut: $2.09/lf

Concrete Maintenance Schedule with Associated Costs

Year	Item	Available Quantity	Amount	Units	Present Value Cost
10	Reseal Joints	100	6178	lf	$10,594
20	Reseal Joints	100	6178	lf	$8,776

Escalation rate applied to $1.75/lf
Mtrl. Inf. Rate – CPI = 1.11%

Concrete | Asphalt

Costs

Concrete Annual Maintenance	0.00	$ / SY
Full-Depth Repairs	90.00	$ / SY
Partial-Depth Repairs	150.00	$ / SY
Diamond Grinding	5.50	$ / SY

Joint Sealant

○ No Seal		
◉ Hot-Pour Filler in Single Sawcut	2.09	$ / lf
○ Hot-Pour Sealant (w/Backer Rod)	2.00	$ / lf
○ Silicone Sealant (w/Backer Rod)	3.00	$ / lf
○ Preformed Neoprene Compression Seal	5.00	$ / lf

Schedule

Next

Maintenance, Preservation, and Rehab Items: 2

Year	Item	%Quantity	Amount	Units
10	Reseal Joints	100 %	6178	lf
20	Reseal Joints	100 %	6178	lf
0	Reseal Joints	0 %		lf
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		
0	Select Item	0 %		

Asphalt Cost Inputs

Asphalt Annual Maintenance:	$0.00	/ SY
Crack Sealing:	$0.89	/ lf
Milling:	$9.51	

Chip Seal:	$1.50	/ SY
Seal Coat:	$3.00	/ SY

Asphalt Maintenance Schedule with Associated Costs

Year	Item	Amount	Units	Present Value Cost
7	Rout and Seal Cracks	6178	lf	$4,820
15	Mill and Asphalt Overlay	3	in.	$53,695
22	Rout and Seal Cracks	6178	lf	$3,634

Escalation rate applied to $0.81/lf for crack sealing (rout and seal)

Escalation rate applied to $8.06/SY/in for milling (includes mill and overlay)

Costs

Asphalt Annual Maintenance	0.00	$ / SY
Rout and Seal Cracks	0.89	$ / lf
Milling	9.51	$ / SY • in
Chip Seal	3.00	$ / SY
Seal Coat	1.50	$ / SY

Schedule

Next

Maintenance, Preservation, and Rehab Items:

3

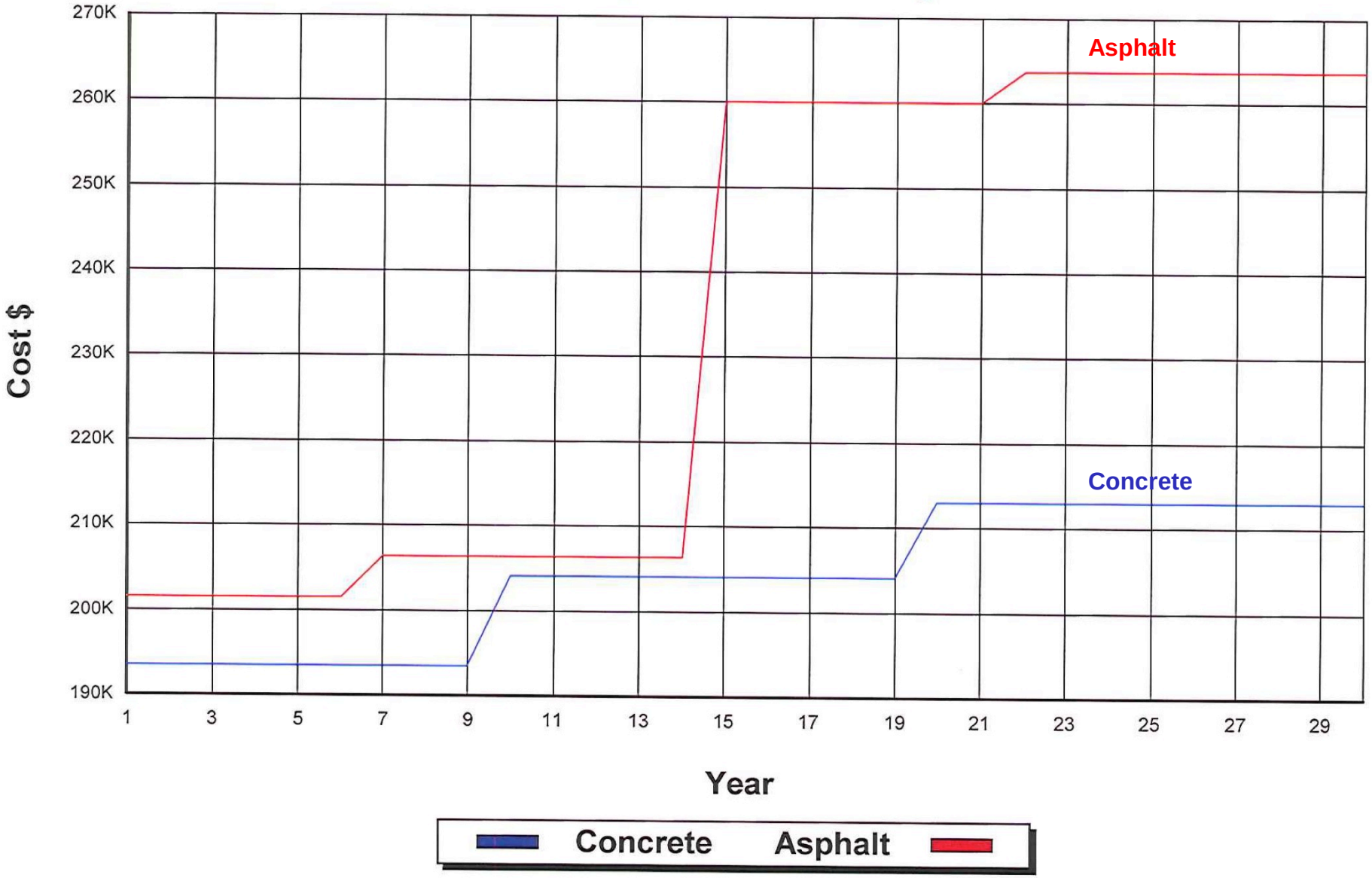
Year	Item	%Quantity	Amount	Units
7	Rout and Seal Cracks	100 %	6178	lf
15	Mill and Asphalt Overlay	100 %	3	in.
22	Rout and Seal Cracks	100 %	6178	lf
0	Rout and Seal Cracks	0 %	0	lf
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	
0	Select Item	0 %	0	units

Cumulative Costs (includes initial costs and present value maintenance costs)

Year	Concrete	Asphalt
1	$193,565	$201,485
2	$193,565	$201,485
3	$193,565	$201,485
4	$193,565	$201,485
5	$193,565	$201,485
6	$193,565	$201,485
7	$193,565	$206,304
8	$193,565	$206,304
9	$193,565	$206,304
10	$204,159	$206,304
11	$204,159	$206,304
12	$204,159	$206,304
13	$204,159	$206,304
14	$204,159	$206,304
15	$204,159	$260,000
16	$204,159	$260,000
17	$204,159	$260,000
18	$204,159	$260,000
19	$204,159	$260,000
20	$212,935	$260,000
21	$212,935	$260,000
22	$212,935	$263,634
23	$212,935	$263,634
24	$212,935	$263,634
25	$212,935	$263,634
26	$212,935	$263,634
27	$212,935	$263,634
28	$212,935	$263,634
29	$212,935	$263,634
30	$212,935	$263,634

StreetPave | Pavement Design & Analysis Software | American Concrete Pavement Association

Life Cycle Cost Analysis



Local Road LCCA Example

- Compare Alternatives:
  - Concrete - Initial Cost: $193,565 / NPV: $212,935
  - Asphalt - Initial Cost: $201,485 / NPV: $263,634

- Initial cost for each alternate is competitive (within 5% of each other)

- The concrete alternate will cost 19% less than the asphalt alternate over the analysis period
  - 91% of Concrete Alternate is initial cost
  - 76% of Asphalt Alternate is initial cost

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Alternate Pavement Design Bidding

- Equivalent designs
  - AASHTO
    - Pavement ME Design
    - WinPAS (based on 1993 empirical AASHTO design)
  - StreetPave
- Equivalent pay items (both by volume or area)
- Include Life Cycle Cost Analysis (LCCA)

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MoDOT LCCA Example

Life-Cycle Cost Adjustment Worksheet

last revised January 2008

Cost per lane Mile
$78,208.81

Job Number	J7I0599
County	Lawrence
Route	I-44
Call	701
Letting Date	09/19/08

This Documentation should be filed with all other Final Engineer's Estimate Documentation. Also include a copy along with the pavement estimation worksheet in the Alternate Pavements Notebook.

Total Area of Paving	18,815.2	SY
Area of Traveled Way	14,762.0	SY
Area of Shoulders	0.0	SY

Spreadsheets use OMB Real Interest Rates January 2008

5-Year	10-Year	20-Year	25-Year*	30-Year +
2.300%	2.600%	2.800%	2.800%	2.800%

*Straight Line Interpolation From Published Rates

SP125 Weight Factor 1.97 Tons/CY

Estimated Unit Price for SP125BSMR 76-22	$92.90	/Ton
Estimated Unit Price for BP-1 - Shoulders	$0.00	/Ton
Estimated Unit Price for Cold Milling	$1.32	/SY
Estimated Unit Price for Diamond Grinding	$2.62	/SY
Estimated Unit Price for Pavement Repair**	$125.00	/SY

**Includes all related Pavement Repair Items

Estimated Unit Prices Based off of a 5 mile Project for Future Operations

Total LCCA Adjustment Factor $163,994

For Job Special Provision **$164,000**

MoDOT AC Projection

	% or Thick. (in.)	Year	Quantity	Unit	Unit Price	Cost	2006 Present Worth
20 Year Maintenance							
Discount Rate: 2.800%							
Mill Surface Lift Traveled Way	1	20	14,762	SY	$1.32	$19,437	$11,188
AC Resurfacing Traveled Way	1.75	20	1,414	TON	$92.90	$131,326	$75,594
Miscellaneous	11.7%	20	1	Price	$17,639.21	$17,639	$10,154
Mobilization	4.6%	20	1	Price	$7,746.48	$7,746	$4,459
Construction added costs	10.1%	20	1	Price	$17,790.96	$17,791	$10,241
33 Year Maintenance							
Discount Rate: 2.800%							
Mill Surface Lift - all	1	33	18,815	SY	$1.32	$24,773	$9,959
AC Resurfacing (minus shoulders)	1.75	33	1,802	TON	$92.90	$167,384	$67,289
Resurfacing Shoulders	1.75	33	0	TON	$0.00	$0	$0
Miscellaneous	11.7%	33	1	Price	$22,482.40	$22,482	$9,038
Mobilization	4.6%	33	1	Price	$9,873.43	$9,873	$3,969
Construction added costs	10.1%	33	1	Price	$22,675.82	$22,676	$9,116
Years in analysis: 45	**Total Cost:**					$441,128	$211,006
Discount Rate: 2.800%							
	Equivalent Uniform Annual Cost:						$8,305

MoDOT PCC Projection

	% or Thick. (in.)	Year	Quantity	Unit	Unit Price	Cost	2006 Present Worth
25 Year Maintenance							
Discount Rate: 2.800%							
Traveled Way Slab Replacements	1.5%	25	221	SY	$125.00	$27,679	$13,878
Diamond Grinding of Traveled Way		25	14,762	SY	$2.62	$38,626	$19,366
Miscellaneous	23.0%	25	1	Price	$15,250.06	$15,250	$7,646
Mobilization	4.9%	25	1	Price	$3,996.18	$3,996	$2,004
Construction added costs	9.6%	25	1	Price	$8,212.88	$8,213	$4,118
Years in analysis: 45			**Total Cost:**			$93,764	$47,012
Discount Rate: 2.800%							
	Equivalent Uniform Annual Cost:						$1,850

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Thank you!

Questions?

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