Recognizing Life Cycle Cost Analysis Sensitivity for Pavement Preservation Treatments

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Life Cycle Cost Analysis Issues

- Exclusive use of Present Value Analysis for public projects.
- Selection of a period of analysis.
- Selection of an interest rate.
- Calculation of asset residual value.
- Calculation of user costs.
- Use of the same interest rate for both agency and user costs.
- The lack of recognition of the value of cost certainty when comparing materials with different levels of historic volatility.

Present Value Analysis Issues

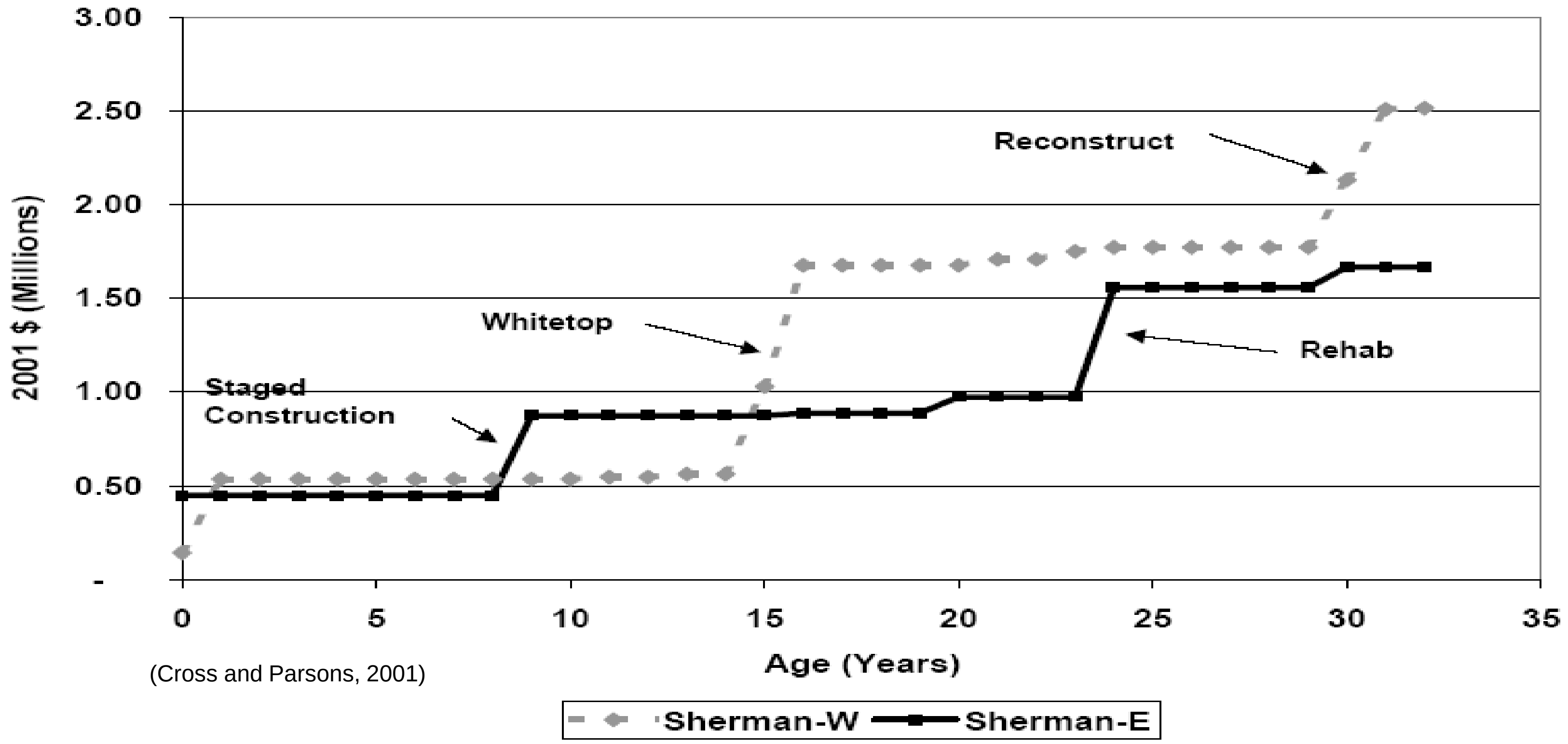
State and Federal governments mandate the use of Net Present Value (NPV) for life cycle cost analysis of public project design alternatives.

1. Replication of multiple services lives is an artificial computational trick that in no way models actual circumstances.
2. Calculation of residual value for most assets is difficult without empirical deterioration models.
3. Mandated use of PV analysis precludes the use of Equivalent Uniform Annual Cost (EUAC) analysis which furnishes a technically viable solution to issues 1 and 2

Period of Analysis Issues

- LCCA outcomes are sensitive to the period of analysis.
- Arbitrary selection can bias the output.
- Example – Asphalt pavement versus Concrete.
  - Asphalt service life 12-15 years and cost to reconstruct relatively low.
  - Concrete service life 20-30 years and cost to reconstruct is more than initial cost because of high demolition cost.
- Thus, if period does not include a concrete reconstruction cost, concrete wins.

The DOT's Dream: Concrete vs Asphalt



(Cross and Parsons, 2001)

Concrete Asphalt

Life Cycle Cost Analysis Issues

Problem: What is the proper discount rate to use in life cycle cost analysis to make pavement design decisions IAW federal funding regulations?.... Or any other LCC-based design decisions?

Agency	Required LCCA Interest Rate	Agency	Required LCCA Interest Rate
FHWA	3%-5%	North Carolina DOT	4%
Arizona DOT	4%	Pennsylvania DOT	6%
California DOT	5%	Texas DOT	5%
Idaho DOT	4%	Washington DOT	4%
Kentucky DOT	3%-10%	Wisconsin DOT	5%
Nevada DOT	4%	New Zealand Transport Agency	8%
Maryland DOT	6%	British Columbia Ministry of Transportation	6%
Michigan DOT	3.90%	Ontario Ministry of Transportation	5%

Possible Discount Rates

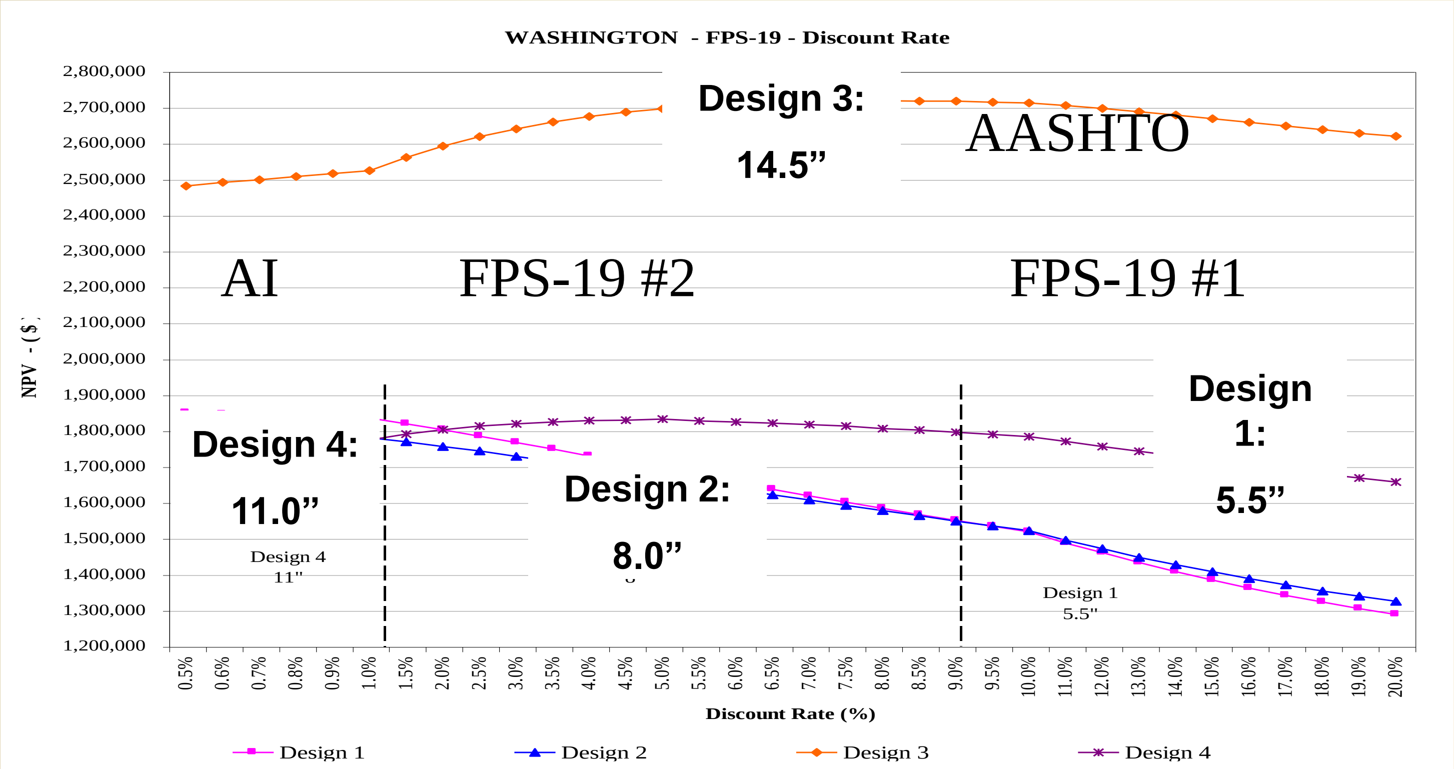
- Global: loss in buying power of the US dollar. FHWA approved approach
- Industry based: Inflation in transportation construction projects – construction cost indices.
- Material based (econometric): Inflation of major commodity – asphalt, Portland cement, steel, etc.

Different Discount Rates: Monte Carlo Results

Statistical Measures of Simulation Results						
Statistic	Asphalt CalTrans ACP Index	Concrete CalTrans PCCP Index	Asphalt CalTrans CCI Index	Concrete CalTrans CCI Index	Asphalt ENR CCI Index	Concrete ENR CCI Index
Minimum	3.60E+06	1.07E+07	3.59E+06	1.07E+07	3.59E+06	1.07E+07
Mean	1.96E+08	1.22E+14	2.76E+07	2.77E+07	1.10E+07	2.75E+07
Maximum	6.80E+10	1.18E+17	7.87E+09	5.76E+09	1.53E+09	1.30E+10
Std Dev	2.87E+09	3.74E+15	2.66E+08	1.93E+08	5.43E+07	4.10E+08
Variance	8.24E+18	1.40E+31	7.09E+16	3.74E+16	2.95E+15	1.68E+17
Winning Alternative	Asphalt always has lower expected life cycle cost.		Asphalt to $24.5 M then Concrete		Asphalt to $26.5 M then Concrete	

Conclusion: Need research to develop state-level econometric discount rates for pavement LCCA-based design.

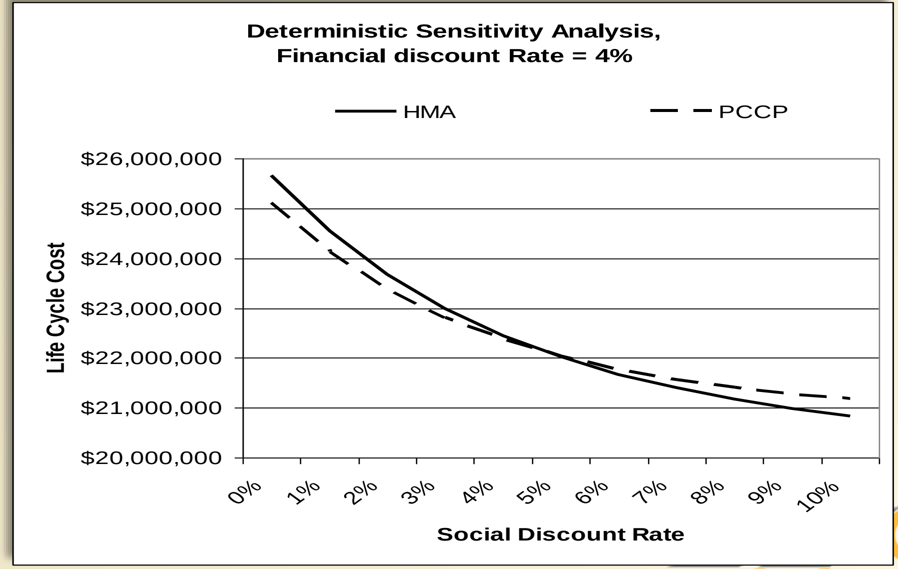
Impact of Interest Rate Sensitivity on Design



When the **ECONOMIST** picks the rate – the **ENGINEER** no longer controls the design

Same Rate for Agency and User Costs

- Standard is use the same rate for both.
- World Bank uses a "social discount rate" to evaluate infrastructure projects.
  - Recognizes that the impact of discounting on humans impacted by project and applied to user costs.
  - Financial rate is used for capital costs.
  - Figure shows sensitivity to this issue.



User Cost Issues

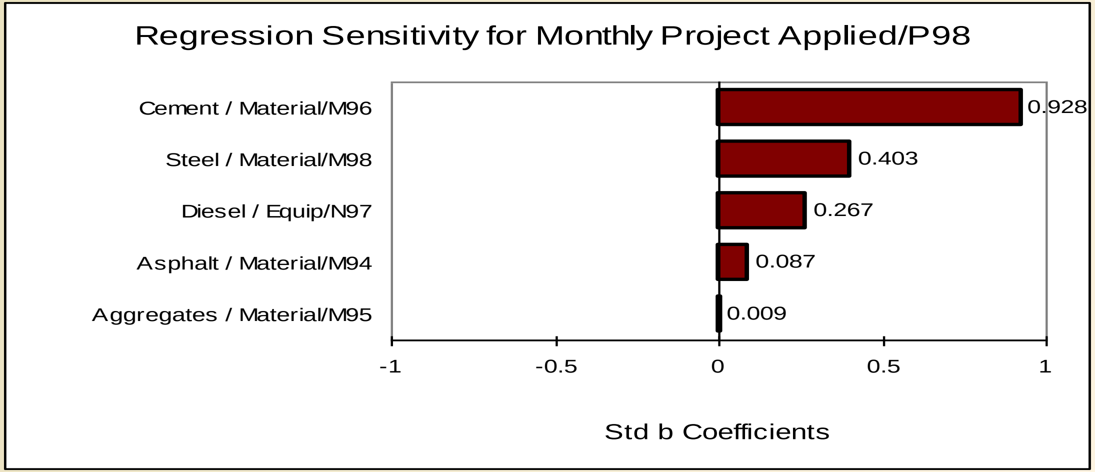
- Research estimates user cost of an urban freeway can exceed $10,000 per lane-mile per day.
- Thus, a 5-mile 8-lane freeway could incur $400,000 per day in user costs of construction.
- These can outstrip the actual capital costs.
- Use of a “weighted” amount is an option
  - i.e. user costs @ 20% & capital costs @ 80%
- However, the weight is arbitrary and the output can be manipulated by manipulating the weights.
- Adding user costs favors:
  - Design that are fast to build and/or have longer service lives.
  - Long term analysis to put a value on a short-term aspect

Residual Value Issues

- An infrastructure asset does have value after its service life is exceeded.
- Current methods use depreciation theory
  - FHWA uses straight-line
  - International agencies use empirical deterioration models
- Two questions have not been satisfactorily answered:
  - Does an asset REALLY have value if it costs more to remove than the value of its materials?
  - Does renovating an asset, which actually incurs a cost not a benefit, cancel the residual value?

Volatility Issues

- How certain are the numbers used in LCCA?
  - When an agency does a cost estimate for a job to built in 2 years, it includes a contingency for uncertainty.
  - Why don't we include a contingency in LCCA that spans 50 years?
  - Perhaps design-oriented LCCA should design around materials that are the least volatile



LCCA in Transportation

- Limited application due to complexity
- Very sensitive to discount rate & analysis period
- Limited at project/implementation level
- No specific stochastic LCCA/PPT – adapted tool
- Network-level LCCA tool (FHWA CASE STUDIES):
  - not applied to PPT or needs to be customized for PPT
- Economic analysis tools still being developed (FHWA, 2007)
- No consensus among SHAs
- SHA to develop own tools (Hall et al, 2003)

Deterministic v. Stochastic LCCA

LCCA to determine most cost-effective alternative and could justify pavement preservation treatment decisions

- Deterministic approach:
  *traditional approach in transportation
  *point estimate based on input assumptions
  *limited sensitivity analysis
  *less complex than stochastic approach
- Stochastic approach:
  *exposes inherent uncertainties (simultaneously)
  *identifies/quantifies risk associated with commodity price volatility
  *to address budget issues and mitigate risk
  *recommended by the FHWA (if uncertainty impact)

Deterministic EUAC for PPT evaluation

HMA EUAC ($/lane-mile), Deterministic Method			
	Discount Rate		
Service Life (YR)	**3%**	**4%**	**5%**
8	4,917	5,086	5,259
10	4,387	4,551	4,719
12	3,759	3,933	4,111

Stochastic EUAC for PPT evaluation

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$4,551 falls at the 37th percentile

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12	3,759	3,933	4,111

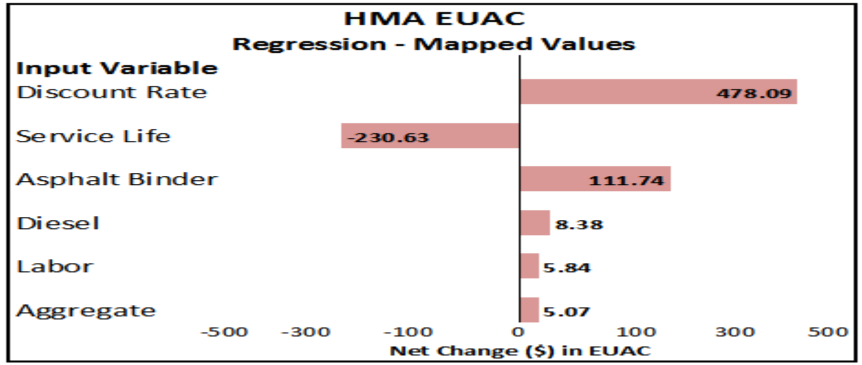
$3,759 falls at the 5th percentile

Stochastic EUAC for PPT evaluation

HMA EUAC ($/lane-mile), Deterministic Method			
	Discount Rate		
Service Life (YR)	3%	4%	5%
8	4,917	5,086	5,259
10	4,387	4,551	4,719
12	3,759	3,933	4,111

$5,259 falls at the 82nd percentile

EUAC & Risk Analysis
Sensitivity Analysis: Regression



Input Variable	St. Deviation	Regression Coefficient	Net Change in EUAC
Discount Rate	2.76%	0.869	478.09
Service Life	1.2 Years	-0.419	-230.63
Asphalt Binder	$0.13	0.203	111.74
Diesel	$0.008	0.015	8.38
Labor	$0.006	0.011	5.84
Aggregate	$0.006	0.009	5.07

LCCA Example

	1" HMA		5/8" Chip Seal	
Deterministic	Service Life, Discount Rate	EUAC ($/lane-mile)	Service Life, Discount Rate	EUAC ($/lane-mile)
Low	12-YR, 3%	3,759	6-YR, 3%	3,019
Average	10-YR, 4%	4,551	4-YR, 4%	4,478
High	8-YR, 5%	5,259	2-YR, 5%	6,900
Probabilistic				
Mean		4,742		4,574
St. Deviation		557		983
5th Percentile		3,844		3,288
95th Percentile		5,669		6,505
Max. Value		7,191		8,633
		Net Change in EUAC		Net Change in EUAC
Regression Analysis (Service Life)		-230.63		-911.66

LCCA Example

	1" HMA		5/8" Chip Seal	
Deterministic	Service Life, Discount Rate	EUAC ($/lane-mile) (percentile)	Service Life, Discount Rate	EUAC ($/lane-mile) (percentile)
Low	12-YR, 3%	3,759 (4th)	6-YR, 3%	3,019 (P<1st)
Average	10-YR, 4%	4,551 (37th)	4-YR, 4%	4,478 (53rd)
High	8-YR, 5%	5,259 (82nd)	2-YR, 5%	6,900 (99th)
Probabilistic				
Mean		4,742		4,574
St. Deviation		557		983
5th Percentile		3,844		3,288
95th Percentile		5,669		6,505
Max. Value		7,191		8,633
		Net Change in EUAC		Net Change in EUAC
Regression Analysis (Service Life)		-230.63		-911.66

Conclusions

- Stochastic LCCA is practical at the PPT level, facilitated by software
- Deterministic LCCA provides comparable results to stochastic LCCA, is less complex, and is appropriate when uncertainty is not expected to affect results
- Probabilistic treatment of volatile commodities can expose LCCA sensitivities and enhance LCCA process
- Stochastic LCCA can enhance a pavement engineer's ability to address budget issues, mitigate risk and justify PPT decisions

Summary

- Design-oriented LCCA is not as simple as the Engineering Economics textbooks claim.
  - The books have unintentionally over-simplified the analysis to avoid thorny computational issues
  - This makes it easy to teach to engineers with no formal education in economics and finance.
- Sensitivity analysis MUST be used to understand the dynamics of the LCCA model.
- Monte Carlo simulation can be used to quantify uncertainty.
- The least sensitive option may be the best even if its LCC is higher than another.