Life Cycle Cost Analysis of Full Depth Reclamation versus Traditional Maintenance and Rehabilitation Strategies

Andrew Braham
University of Arkansas

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Motivation in Arkansas for Full Depth Reclamation (FDR)

- Increase of heavy traffic on rural Arkansas' highways
  - Natural gas drilling (fracking) and logging
- Roads not designed for unanticipated heavy loads
- Traditional maintenance/rehabilitation strategies not adequate or prohibitively expensive
  - Chip seal
  - Two-inch overlay
  - Mill and fill with two-inch overlay
  - Remove and replace

Arkansas Highway 98

FDR is a potential solution

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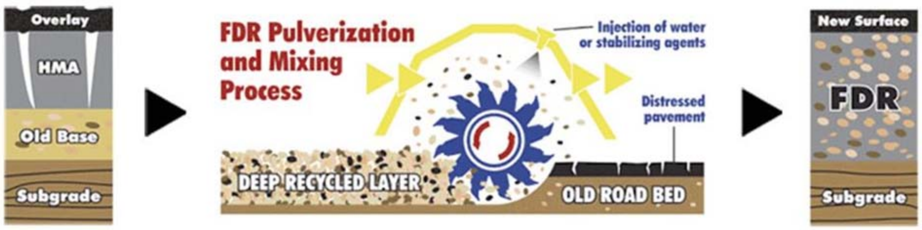
FDR overview

- FDR reclaims, stabilizes, and compacts 8-14" of in-place bound, unbound, and subbase material
- Material stabilized by adding asphalt emulsion, asphalt foam, or Portland cement
- After mixing complete, material compacted and a surface course is placed



(arscompanies.com)

Can lead to decrease in virgin materials, and economic/environmental savings

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Life Cycle Cost Analysis Procedure
Federal Highway Administration

1. Establish alternative pavement design strategies for analysis period,
2. Determine performance periods and activity timing,
3. Estimate agency costs,
4. Estimate user costs,
5. Develop expenditure stream diagrams,
6. Compute Net Present Value (NPV),
7. Analyze results and reevaluate design strategies.

Relatively straight forward: steps 1-5, 7
6. Compute NPV warrants more discussion

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Net Present Value (NPV) =

$$Initial\ Cost + \sum_{0}^{t_n}\left(\frac{Maintenance\ Cost}{(1+r)^{t_n}}\right) + \sum_{0}^{t_n}\left(\frac{Rehabilitation\ Cost}{(1+r)^{t_n}}\right) - \left(\frac{Salvage\ Cost}{(1+r)^{t_n}}\right)$$

t = time period (yrs)
n = year of analysis
r = discount rate (%)

Salvage Cost =

$$CLR \times \frac{Remaining\ Life\ of\ Last\ Resurfacing}{Service\ Life\ of\ Last\ Resurfacing} + CRI$$

CLR = cost of the last resurfacing
CRI = cost of the lower asphalt layers remaining from the initial construction

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Alternative pavement design strategies (maintenance schedule)

- Traditional in Arkansas
  - Chip seal (6 years)
  - Two-inch overlay (11 years)
  - Mill and fill with two-inches of asphalt concrete (11 years)
  - Removal and replace (11 years)
- FDR rehabilitation techniques
  - Asphalt emulsion (6 years)
  - Asphalt foam (6 years)
  - Portland cement (6 years)

50-year design analysis (assume non-surface layers structurally sound with no deterioration)

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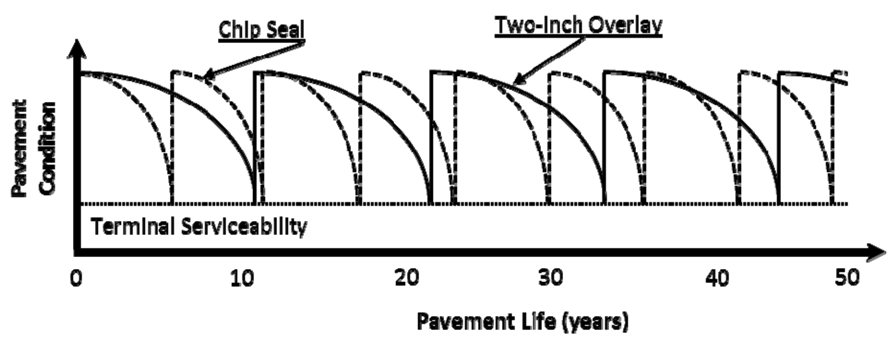
Deterioration curves for chip seal and two-inch overlay



Performed on four Arkansas Highways:
AR98, AR134, AR36, AR5
Increase in traffic and bound layer thickness from left to right

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Agency costs – 2014 weighted averages from Arkansas (cost per lane mile $1,000s)

• Chip seal: emulsion, aggregate	~12
• Two inch overlay: 5% asphalt binder, 95% aggregate	~65
• Mill and fill: cold milling, asphalt binder, aggregate	~77
• Remove and replace: cold milling, base course, asphalt binder, aggregate	~264 –502
• FDR: stabilization process, cement/emulsion, tack coat + chip seal or two inch overlay	~78-218

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Ranges from different structural numbers

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User costs – function of auto delay, truck delay, production rate (cost per lane mile $1,000s)

- Chip seal: emulsion, aggregate ~4-63
- Two inch overlay: 5% asphalt binder, 95% aggregate ~5-76
- Mill and fill: cold milling, asphalt binder, aggregate ~21-315
- Remove and replace: cold milling, base course, asphalt binder, aggregate ~264 –502
- FDR: stabilization process, cement/emulsion, tack coat + chip seal or two inch overlay ~78-218

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Ranges from different highway traffic

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LCCA of two traditional agency costs ($/lane-mile): 5% discount rate

	Chip Seal	Two-inch overlay
Year 0 - Initial Price	$11,990	$65,175
Year 6	$8,947	
Year 11		$38,107
Year 12	$6,677	
Year 18	$4,982	
Year 22		$22,280
Year 24	$3,718	
Year 30	$2,774	
Year 33		$13,027
Year 36	$2,070	
Year 42	$1,545	
Year 44		$7,616
Year 48	$1,153	
Year 50 - Salvage value	$1,074	$5,985

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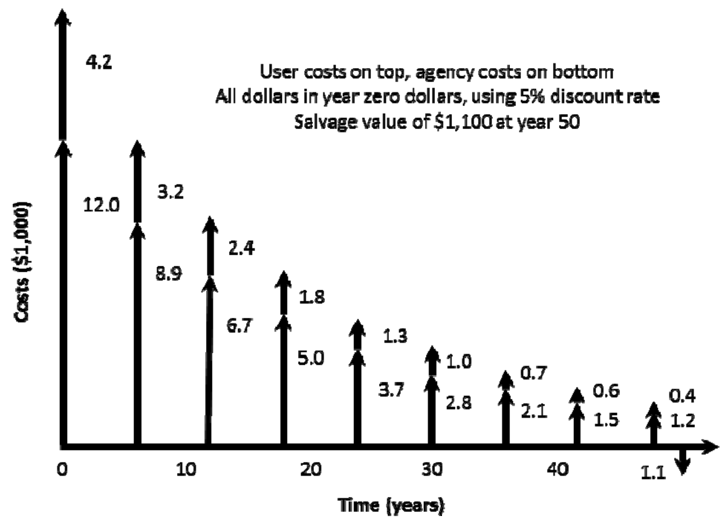
Expenditure stream for chip seal



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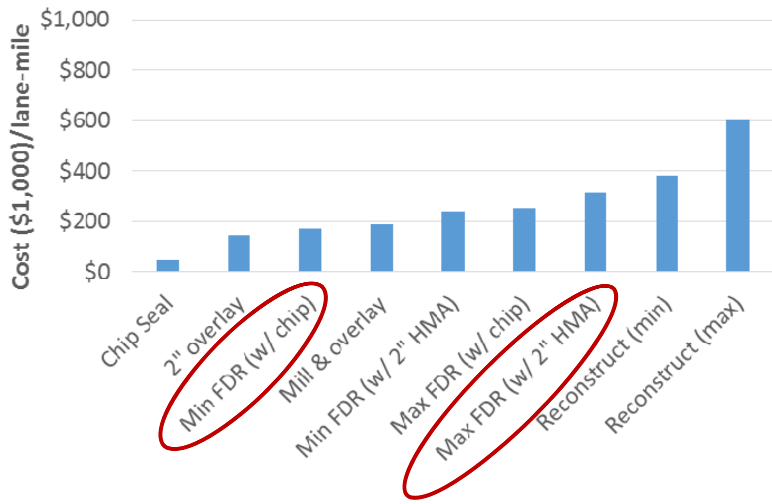
Agency and user costs for AR98



Lowest traffic, least bound – FDR highly competitive

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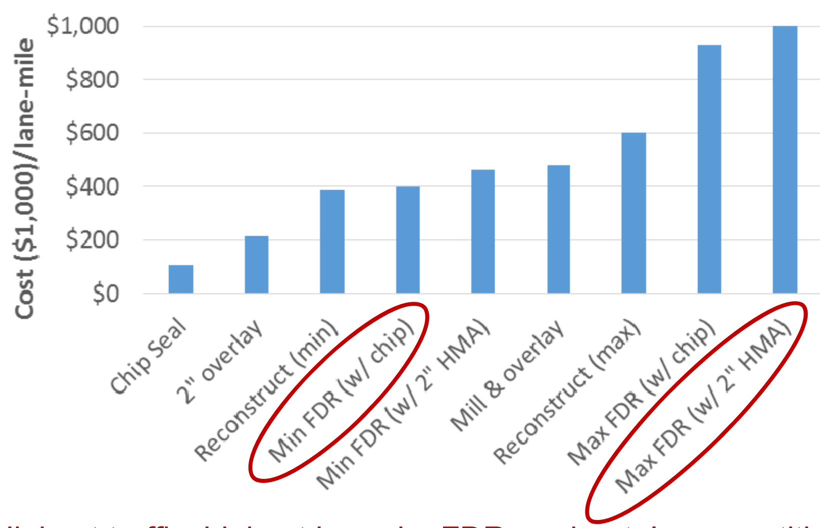
Agency and user costs for AR98



Highest traffic, highest bound – FDR moderately competitive

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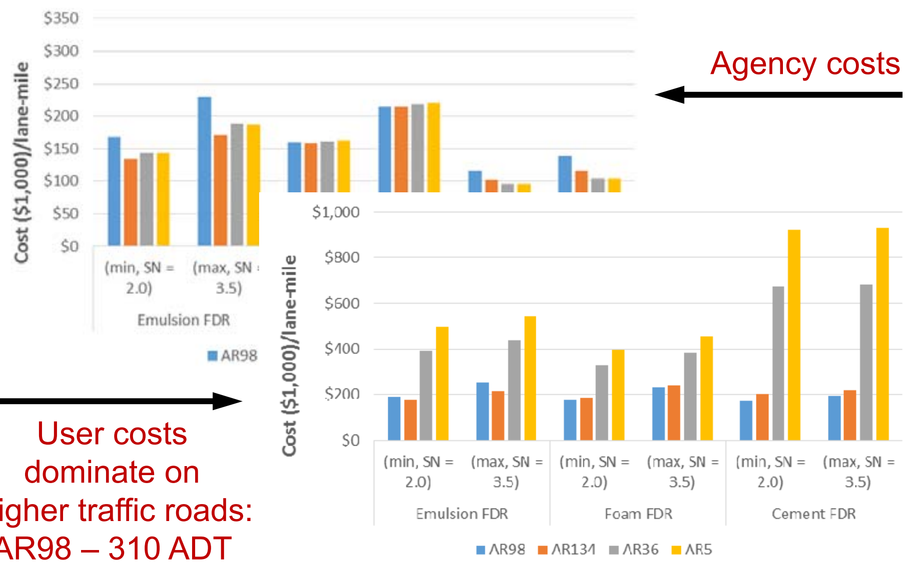
Influence of user costs for FDR – chip seal surface

Agency costs



User costs dominate on higher traffic roads:
AR98 – 310 ADT
AR5 – 4,460 ADT

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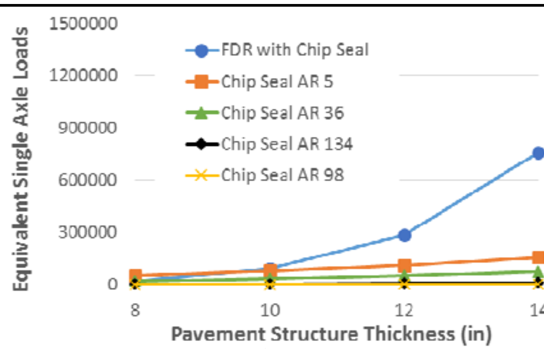
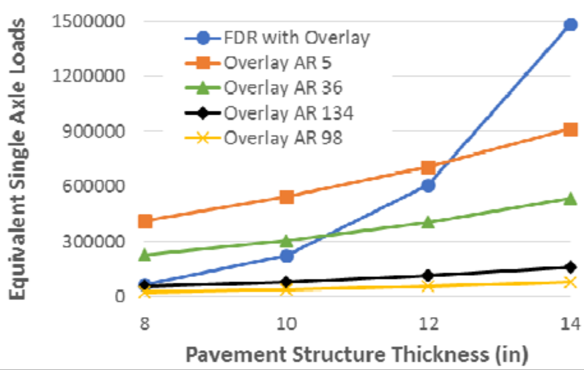


1993 AASHTO structural number ESAL prediction: chip seal and overlay

FDR more appropriate for roadways with initial thinner bound layers



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Conclusions

- FDR versus traditional maintenance and rehabilitation techniques
  - More competitive: lower traffic, thinner bound layers
  - Less competitive: higher traffic, thicker bound layers
- Adding days of user delay increased the cost of FDR significantly
  - User costs: ¼ to 5 times agency costs
- Traffic capacity of FDR increased rapidly at reclaiming depths > 10 inches

Arkansas Highway 134

Thank you, questions?

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Andrew F. Braham, Ph.D., P.E.
Associate Professor
Civil Engineering

4190 Bell Engineering Center
Fayetteville, AR 72701
e-mail: afbraham@uark.edu

Phone: 479-575-6028
Fax: 479-575-7168
www.andrewbraham.com

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