Development of New Life Cycle Cost Modeling

The University of Oklahoma

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Project Objective

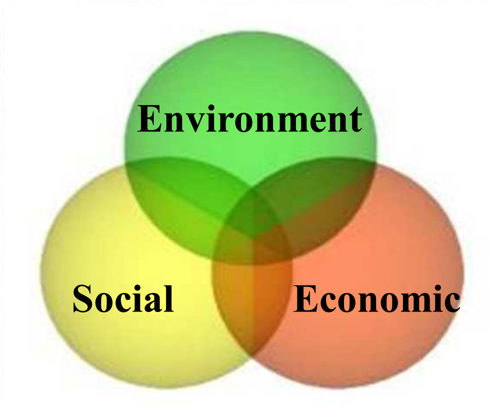
- Conduct a comparative field evaluation of common methods to restore skid resistance
  - Surface treatments
  - Mechanical methods
- 23 asphalt and concrete test sections
  - Monthly testing of skid and macrotexture
  - Result will be deterioration models for each treatment
- Complete a life cycle cost analysis of each method in the study

Test Section Sponsors

- Blastrac, Inc. Edmond, OK
- Penhall Diamond Grinding, Anaheim, CA
- JLT Corp. Cushing, OK
- Ergon Emulsions and Materials, Austin, TX
- Skidabrader, Inc. Ruston, LA
- Polycon, Madison, MS
- Haskell Lemon & Hall Brothers, OKC, OK
- Pathway Services, Tulsa, OK
- Calumet Lubricants, Shreveport, LA

Background and Motivation

- ODOT latest APP: transportation system preservation - critical part of mission
- Economic Analysis: vital transportation decision-making component (sustainability)
- Substantial issues with LCCA theory when applied to preservation.



Sustainability - Triple Bottom Line, (AASHTO, 2009)

Current LCCA in Transportation

- Recommended by FHWA
- Limited application due to complexity
- Very sensitive to discount rate & analysis period
- Limited at project/implementation level
- No specific 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)
- PPT alternatives, SL, cost and productivity data

LCCA

- Treatment cost-effectiveness evaluation based on engineering economic principles

FHWA LCCA procedures:

- 1. Establish design alternatives [and analysis period]
- 2. Determine [performance period and] activity timing
- 3. Estimate costs [agency and user]
- 4. Compute [net present value] life cycle costs
- 5. Analyze results
- 6. Reevaluate design strategies

Net Present Value AP Selection Methods

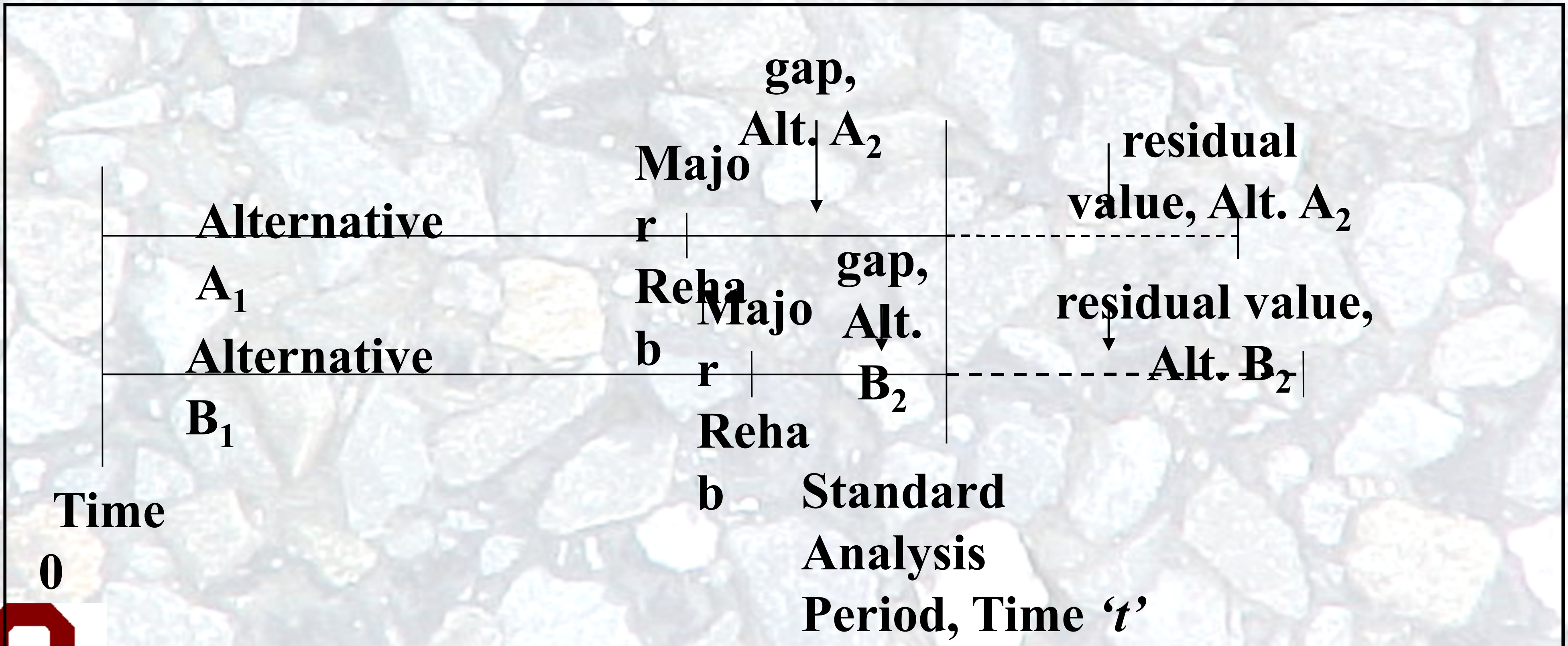
1. Establish [PPT] alternatives and analysis period:
   NPV: analysis period = a common period for all alternatives

- set AP equal to the shortest life among alternatives
- set AP equal to the longest life among alternatives
- set AP equal to the least common multiple of the lives of the various alternatives
- use a standard AP, such as 10 years
- set the AP equal to the period the best suits the organization's need for the investment
- use an infinitely long AP

(White et al, 2010)

FHWA LCCA procedure

1. Establish design alternatives [and analysis period]



Standard Analysis Period, One Major Rehabilitation Accommodated

LCCA
adapted to PPT alternative evaluation

Equivalent Uniform Annual Cost LCCA procedures:

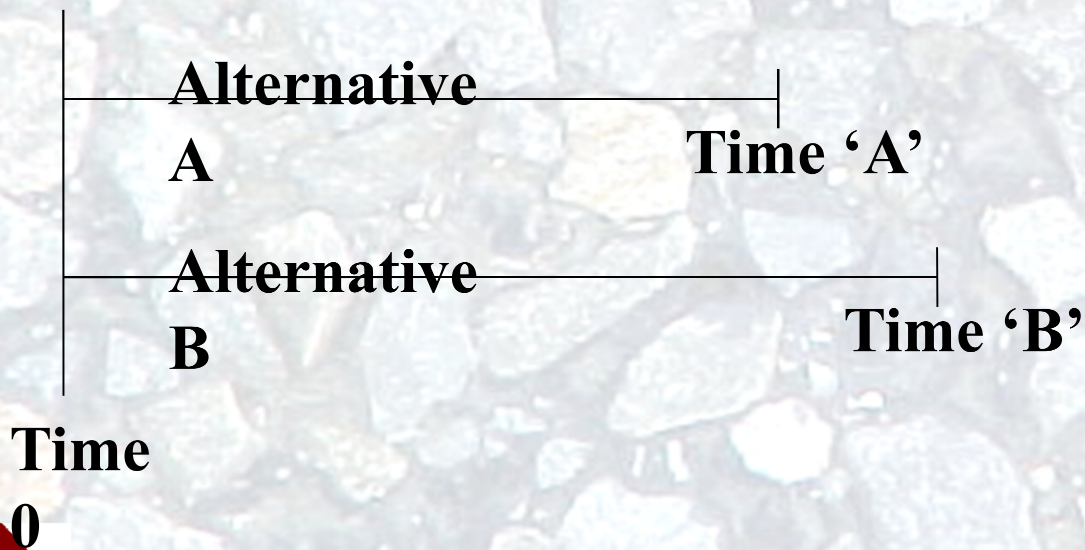
- 1. Establish design alternatives
  [SL_{alt} = analysis $period_{alt}$]
- 2. Determine [performance period and] activity timing
  [SL_{alt} = MIN{microtexture, macrotexture, expected}]
- 3. Estimate costs [agency and user]
- 4. Compute [EUAC] life cycle costs

  [$EUAC(i\%)_{alt}$ = **[∑P] [i(1+i)n ÷ (1+i)n -1)]]**
- 5. Analyze results
- 6. Reevaluate design strategies

Equivalent Uniform Annual Cost (EUAC)

1. Establish design alternatives

   [Analysis period$_{alt}$ = SL$_{alt}$]



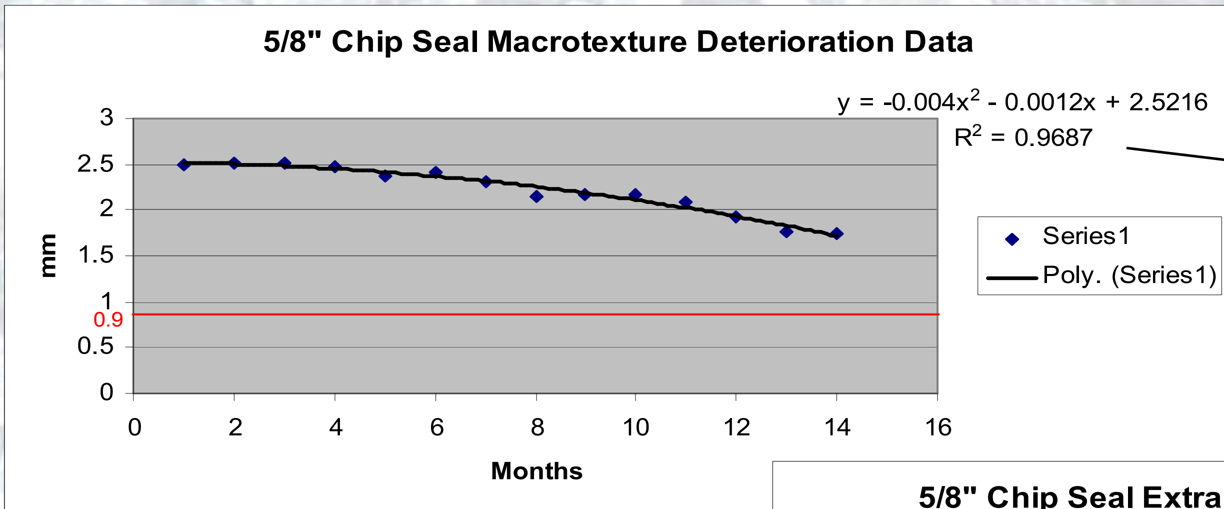
Equivalent Uniform Annual Cost for Unequal-Life Alternatives

Engineering Technical Data

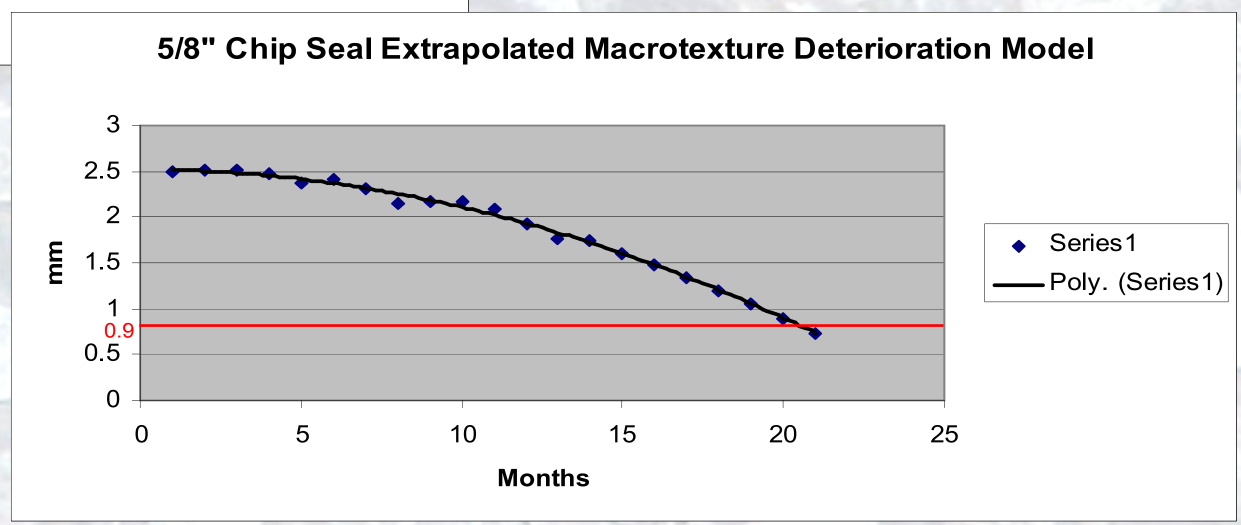
2. Determine [performance period and] activity timing

[SL_{alt} = MIN{microtexture, macrotexture, expected}]

- Field Trial Deterioration Models – Macrotexture, chip seal



Coefficient of Determination: 0.9687



EUAC for PPT evaluation

2. Determine [performance period and] activity timing
   [SL_{alt} = MIN{microtexture, macrotexture, expected}]

Pavement Preservation Treatment	Service Life (years)			
	Microtexture	Macrotexture	ODOT & Lit. Review	Minimum
1" Hot Mix Asphalt Mill & Inlay (HMA)	> 10	N/A	10	10
Open Graded Friction Course (OGFC)	> 10	5.3 years	10	5.3
5/8" Chip Seal	3.8	1.8	5	1.8
Pavement Retexturing, Abrading	>5	N/A	2	2
Pavement Retexturing, Shotblasting	>5	N/A	2	2

Treatment Service Life Based on Extrapolated Field Data

PPT EUAC Model

4. Calculate EUAC, (Continuous Mode)
[SL_{alt} = MIN{microtexture, macrotexture, expected}]

Microsoft Excel - PPLCCA (A) M

ALTERNATE COMPARISON

ALT #	Construction	Maintenance	User Delay	Annual Total
1	7,312	0	217	7,529
2	5,626	578	230	6,434
3	3,472	895	329	4,696

ALT #	Description	EUAC	Rank	Difference
1	Bituminous ODOT Standard 5/8" chip seal	7,529	3	60.32%
2	Bituminous Open Graded Friction Course (OGFC)	6,434	2	37.00%
3	Bituminous 1" Hot Mix Asphalt mill & inlay (HMA)	4,696	1	

UserDelay / Dimension / Quantity / InitialConst. / Bit.Maint. / Bit.Maint.Working Days / Con.Maint. / Con.Maint.Working Days / LifeCycleCost / Alt.Com. / CALCS

<u>Intial Cost, SL</u>:
Chip seal: $12.5 k, 1.8y (macro)
OGFC: $26.5 k, 5.3y (macro)
1'' HMA $28 k, 10y

EUAC (Continuous Mode)
Sensitivity Analysis

4. Calculate EUAC, (Continuous Mode)
[SL_{alt} = MIN{microtexture, macrotexture, expected}]

Microsoft Excel - PPLCCA (A) M check

ALTERNATE COMPARISON

ALT #	Construction	Maintenance	User Delay	Annual Total
1	3,600	783	313	4,696
2	5,626	578	536	6,740
3	3,472	895	329	4,696

ALT #	Description	EUAC	Rank	Difference
1	Bituminous ODOT Standard 5/8" chip seal	4,696	1	
2	Bituminous Open Graded Friction Course (OGFC)	6,740	3	43.53%
3	Bituminous 1" Hot Mix Asphalt mill & inlay (HMA)	4,696	2	0.01%

<u>Intial Cost, SL</u>:

Chip seal: $12.5 k, 3.8y (micro)

OGFC: $26.5 k, 5.3y (macro)

1" HMA $28 k, 10y

EUAC (Continuous Mode)
Sensitivity Analysis

4. Calculate EUAC, (Continuous Mode)
[SL_{alt} = MIN{microtexture, macrotexture, expected}]

Microsoft Excel - PPLCCA (A) M

ALTERNATE COMPARISON

ALT #	Construction	Maintenance	User Delay	Annual Total
1	2,799	609	243	3,651
2	3,255	895	310	4,460
3	3,472	895	329	4,696

ALT #	Description	EUAC	Rank	Difference
1	Bituminous ODOT Standard 5/8" chip seal	3,651	1	
2	Bituminous Open Graded Friction Course (OGFC)	4,460	2	22.15%
3	Bituminous 1" Hot Mix Asphalt mill & inlay (HMA)	4,696	3	28.62%

Intial Cost, expected SL:

Chip seal: $12.5 k, 5y
OGFC: $26.5 k, 10y
1" HMA $28 k, 10y

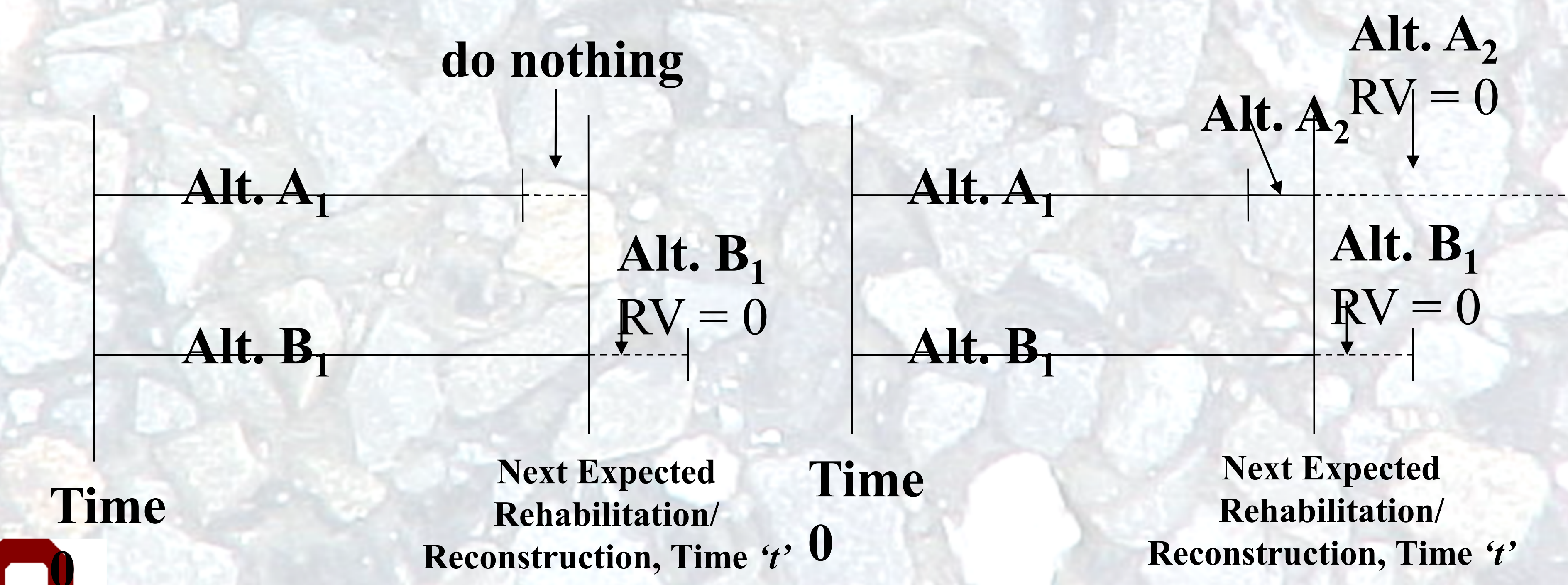
EUAC-Continuous Mode
(same ranking as NPV, various AP)

PAVEMENT TREATMENTS	Agency Costs	Analysis Period	Rank
EUAC			
ODOT Standard 5/8" chip seal (5-yr)	3,408	5	1
OGFC (10-yr)	4,150	10	2
1" Hot Mix Asphalt mill/inlay (10-yr)	4,367	10	3
Present Value - Shortest Life			
ODOT Standard 5/8" chip seal (5-yr)	15,172	5	1
OGFC (10-yr)	20,463	5	2
1" Hot Mix Asphalt mill/inlay (10-yr)	21,343	5	3
Present Value - Longest Life			
ODOT Standard 5/8" chip seal (5-yr)	30,344	10	1
OGFC (10-yr)	33,663	10	2
1" Hot Mix Asphalt mill/inlay (10-yr)	35,423	10	3
Present Value - Standard Period & LCM			
ODOT Standard 5/8" chip seal (5-yr)	60,688	20	1
OGFC (10-yr)	67,326	20	2
1" Hot Mix Asphalt mill/inlay (10-yr)	70,846	20	3

EUAC
Terminal Mode

1. Establish design alternatives

   [analysis period$_{alt}$ = SL$_{alt}$]



Do-Nothing Scenario vs. Fill-the-Gap Scenario

EUAC

Terminal Mode, Expected or Truncated SL

Microsoft Excel - PPLCCA (A)

A1 — PAVEMENT TREATMENT ALTERNATES COMPARED IN LIFE CYCLE COST ANALYSIS

PAVEMENT TREATMENT ALTERNATES COMPARED IN LIFE CYCLE COST ANALYSIS

PAVEMENT TYPE	TREATMENT	SERVICE LIFE	Anticipated Service Life
1 Bituminous	A ODOT Standard 5/8" chip seal	5	5
2 Concrete	B Open Graded Friction Course (OGFC)	10	6
	C 1" Hot Mix Asphalt mill & inlay (HMA)	10	6

ALTERNATE #			PAVEMENT DESCRIPTION		Initial Construction Days**
1 :	1	A	Bituminous	ODOT Standard 5/8" chip seal	0.20
2 :	1	B	Bituminous	Open Graded Friction Course (OGFC)	0.20
3 :	1	C	Bituminous	1" Hot Mix Asphalt mill & inlay (HMA)	0.28
4 :	1	D	Bituminous		
5 :	1	E	Bituminous		
6 :	1	F	Bituminous		

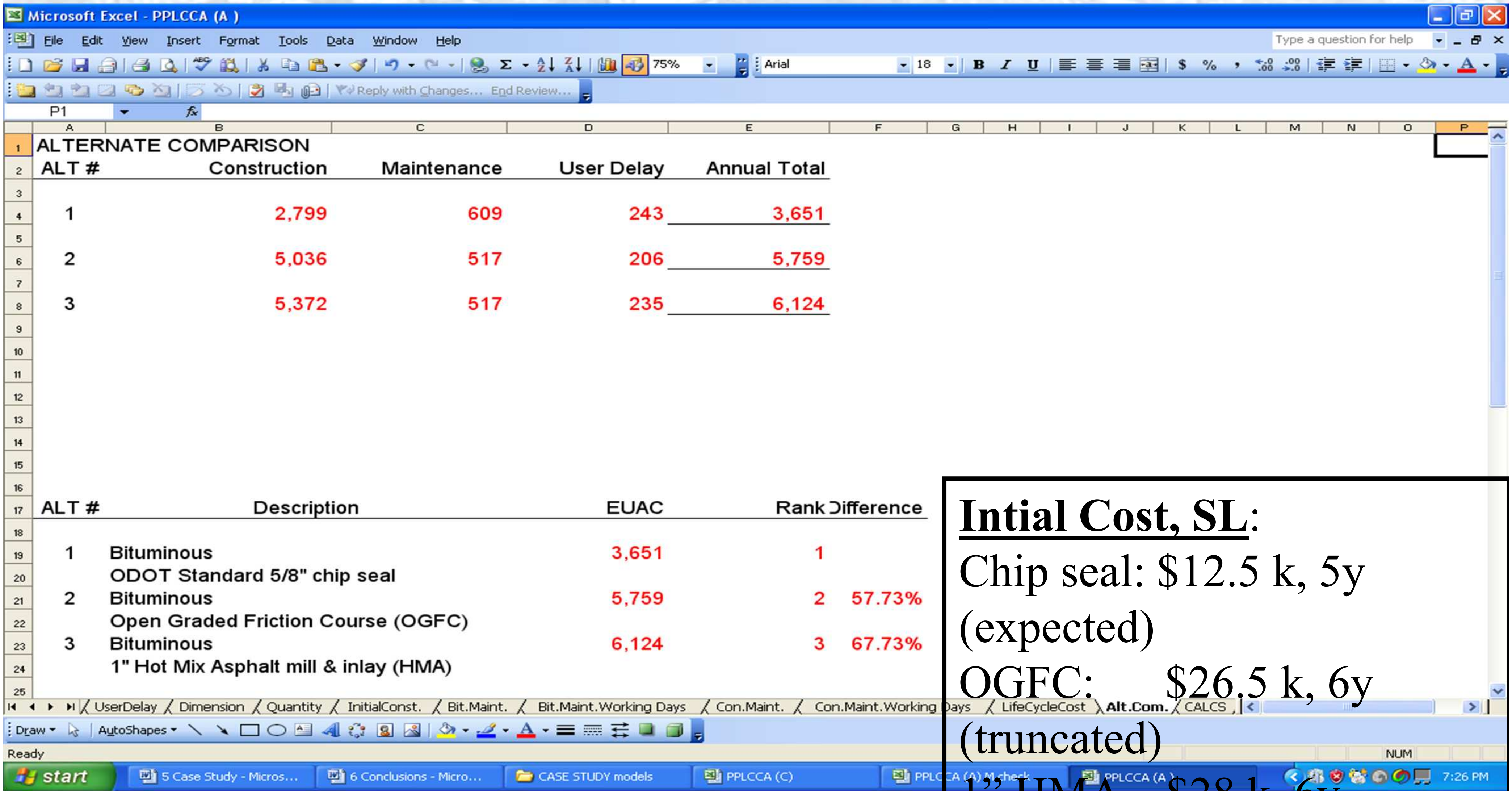
**Days traffic impacted during initial construction project From "Quantity" Worksheet

1.18 DISCOUNT RATE = 4 %

Years until next Rehabilitation/Reconstruction 6

OKPPT / Setup / UserDelay / Dimension / Quantity / InitialConst. / Bit.Maint. / Bit.Maint.Working Days / Con.Maint. / Con.Maint.Working Days / LifeCycleCost

Terminal Mode, Expected or Truncated SL



ALT #	Construction	Maintenance	User Delay	Annual Total
1	2,799	609	243	3,651
2	5,036	517	206	5,759
3	5,372	517	235	6,124

ALT #	Description	EUAC	Rank	Difference
1	Bituminous ODOT Standard 5/8" chip seal	3,651	1	
2	Bituminous Open Graded Friction Course (OGFC)	5,759	2	57.73%
3	Bituminous 1" Hot Mix Asphalt mill & inlay (HMA)	6,124	3	67.73%

<u>Intial Cost, SL</u>:

Chip seal: $12.5 k, 5y (expected)

OGFC: $26.5 k, 6y (truncated)

1" HMA $28 k, 6Y

Conclusions

- Economic + engineering data can be correlated to produce meaningful, standardized economic and life cycle cost analysis (LCCA) information that would assist pavement managers in selecting an alternative that would yield extended service lives of Oklahoma pavements.

- EUAC is the most efficient, appropriate vehicle for determining PPT (short-term) cost effectiveness

- EUAC: treatment-relevant input, pavement manager-relevant output