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700 Life-Cycle Cost Analysis

700.1 Introduction

Life-Cycle Cost Analysis (LCCA) is a process for evaluating the economic worth of a pavement segment by analyzing initial costs and discounted future costs such as preventive maintenance, resurfacing, rehabilitation, and reconstruction costs over a defined analysis period. Personal and District preferences must be set aside to attempt to come up with a fair, unbiased LCCA. It is important to be fair to all alternatives in terms of price and performance. The LCCA is only a tool in the decision-making process, it does not dictate a decision. The results of the LCCA are not decisions but are important information used in reaching decisions.

700.1.1 Alternatives Considered

All reasonable alternatives are to be included in the LCCA. This includes rigid pavement, new or complete replacement; flexible pavement, new or complete replacement; unbonded concrete overlay; crack and seat; rubblize and roll; and whitetopping. Expected cost is not a good reason to exclude an alternative from the analysis. For example, complete replacement is generally the most expensive alternative but it should not be disregarded simply because of the expectation of high cost. The analysis may show replacement as the highest cost but the cost differential between replacement and the other alternatives may be small enough to make replacement the better choice.

Sometimes it is necessary to eliminate alternatives because of the overlay thickness and problems with bridges. Particularly on urban projects where there may be a high number of at-grade and overhead bridges, alternatives which require a thick overlay and therefore a significant increase in elevation may not be good choices. Some preliminary investigation should be done to determine the amount of pavement removal and undercutting necessary to meet at-grade bridges and provide clearance under overhead bridges. If the amount of removal necessary for an alternative exceeds about 40% of the pavement, assuming none of the bridges are jacked, then it may not be necessary to consider that alternative.

700.1.2 Analysis Period

The LCCA analysis period for new pavements and major rehabilitations is 35 years. Because the analysis period exceeds the structural design life, future maintenance and rehabilitation actions must be predicted and included in the analysis to keep the pavement in serviceable condition for the 35-year period.

700.1.3 Estimated Prices

Prices should be estimated based on recent projects; similar quantities; and, where possible, geographic proximity. All prices, for both initial construction and future maintenance, are to be estimated using current bid prices. No escalation is to be given for inflation. The analysis is performed using constant (or real) dollar values and real discount rates instead of using inflated (or nominal) dollar values and nominal discount rates.

Prices should be relative for all projects. If low prices are selected for one alternative, then low prices must be used for all alternatives. Prices should not be manipulated to achieve the desired outcome. No unusually high or low prices should be used without solid justification.

The use of statewide average prices is discouraged. The state averages, while weighted, tend to be too high due to all the small quantity jobs. Most LCCA's involve large quantities and the prices come in much lower than the statewide averages.

700.1.4 Discount Rate

Rather than choose one explicit discount rate, ODOT uses a range of rates to see how the discount rate affects the outcome. Total life-cycle cost is calculated for discount rates of 0, 1, 2, 3, 4, 5, and 6 percent. Results are then displayed in tabular and graphical form to see how the discount rate affects the apparent least-cost alternative.

701 Initial Construction

All alternatives for initial construction are designed using the procedures outlined in this Manual and in accordance with Appendix A, Pavement Design & Selection Process. Initial construction is considered to take place in year zero.

All pavement items are to be included in the analysis such as excavation, subgrade compaction, pavement removed, base, free draining base, and pavement. Non-pavement items and items common to all alternatives can be neglected. Items such as striping, signing, lighting, guardrail, barrier, underdrains, culverts, bridges, embankment, etc., are not pavement items, are essentially equal for all alternatives and are not to be included in the analysis. On new locations, earthwork items including subgrade compaction are common to all pavement alternatives and are essentially equal and therefore do not need to be included.

For rehabilitations that raise the elevation of the existing pavement, a cost needs to be included for maintaining clearance under overhead structures and for meeting elevations of at-grade bridges. For convenience, this is known as the “cost of maintaining clearance”. This cost can be calculated in various ways. One way is to calculate the cost to remove the existing pavement, excavate down, and build back up with new pavement. Another way is to calculate the cost of jacking the bridges, including any approach work necessary on overheads. A third option could be a combination of the two.

It is not important which method is selected for computing cost of maintaining clearance. What is important is that a dollar amount is included in the analysis to account for the cost of maintaining clearance. For convenience, it is recommended to use the same method for all alternatives, i.e. do not remove pavement and excavate for the rubblize alternative and then jack bridges for the unbonded concrete overlay alternative. The method used in the LCCA for computing cost of maintaining clearance does not have to be the actual method used in the plans and in construction.

702 Future Maintenance

702.1 Introduction

The future maintenance required to keep the pavement in serviceable condition for the next 35 years must be predicted. The number one factor when determining required maintenance is engineering judgement. The performance equations given in Figure 101-2 are useful guidance. It is important to note the performance being predicted is for pavements built to current specifications, not 1960's specifications. Many changes and improvements have been made to both asphalt and concrete including such things as PG binders, polymers, gradation changes, free draining bases, epoxy coated steel, non d-cracking aggregates, etc. These changes are expected to result in improved performance and this improved performance should be reflected in the LCCA. Routine maintenance performed by ODOT forces has traditionally been ignored due to lack of dependable data. Only contract maintenance is considered.

ODOT does not use salvage value. This means when choosing the maintenance strategies and timing, the designer must try to balance them such that all alternatives are in approximately the same condition in year 35. Generally the goal is to have each alternative require additional maintenance just after the end of the analysis period. In other words, do not place a thick overlay on one alternative in year 32 while doing nothing since year 25 on the other alternatives.

702.2 Maintenance Schedules

The maintenance strategies and schedules given below are for informational purposes only. This information is intended to give designers some reasonable guidance when deciding the maintenance actions for an LCCA. Wide latitude is given on both the timing and the work predicted. The designer is not restricted to these schedules; but, because of the wide latitude given, anything outside the schedules may be questioned. All thicknesses given are approximate but overlays much thicker or much thinner than those listed are not expected.

The schedules list only major items of work. The designer may need to include additional items. For instance, tack coats are not listed but are required with all overlays. It is not intended that every item listed be used in a given year. For example, concrete pavement shows both an asphalt overlay and diamond grinding as options but never would the two of them be done at the same time. It is further not intended that actions must take place in every one of the years listed. Depending on the expected performance and the actions predicted for the early years, the later rehabilitation(s) may not be necessary.

702.2.1 Flexible Pavement

Flexible pavement includes new pavement on a new alignment and complete replacement of existing pavement.

Year 10 - 15: Thin overlay, 1.25" - 3" (~32 - 75 mm), with or without milling.

Year 18 - 25: Thick overlay, 3" - 7" (~75 - 175 mm), with milling, possibly pavement repairs.

Year 28 - 32: Thin overlay or micro-surfacing or crack sealing.

Many times the third treatment would not be necessary at all depending on the timing of the first two and the thickness of the overlays and their expected performance.

702.2.2 Rigid Pavement

Rigid pavement includes new pavement on a new alignment and complete replacement of existing pavement. Percentages given are of the total mainline pavement area not including shoulders or ramps or turn lanes, etc.

Year 18 - 25: 2% - 10% full-depth rigid repairs, 1% - 5% partial-depth bonded repairs, diamond grinding, 3" - 6" (~75 - 150 mm) overlay, sawing and sealing.

Year 28 - 32: 1% - 3% full- and/or partial-depth repairs, 1.25" - 2" (~32 - 50 mm) second overlay with or without milling, 3" - 4" (~75 - 100 mm) first overlay, sawing and sealing, micro-surfacing, crack sealing, diamond grinding.

Best practice dictates the use of diamond grinding for the first treatment. Placing an asphalt overlay on a concrete pavement brings on a new set of problems and is discouraged as the first predicted maintenance action. Remember, this is the predicted performance of pavements built to current specifications, not 1960's specifications.

Again, in many cases the second treatment may not be necessary at all.

702.2.3 Composite Pavement

Composite pavement is a hybrid of rigid and flexible pavement and requires the maintenance actions of both. It is generally expected to receive full-depth rigid repairs, milling and an overlay every 8 - 12 years.

702.2.4 Unbonded Concrete Overlay

An unbonded concrete overlay is in essence a new concrete pavement built on top of the old. It will require maintenance similar to that for a rigid pavement. It may be reasonable to expect slightly less repair for an unbonded concrete overlay versus new rigid pavement due to the much thicker pavement section.

702.2.5 Fractured Slab Techniques

Fractured slab techniques include crack & seat, and rubblize & roll.

Year 8 - 12: Thin overlay, 1.25" - 4" (~32 - 100 mm) with or without milling.

Year 16 - 22: Thick overlay, 4" - 8" (~100 - 200 mm) with milling, pavement repair.

Year 24 - 32: Thin overlay, 1.25" - 4" (~32 - 100 mm) with or without milling, micro-surfacing, crack sealing.

Fractured slab techniques are more likely to require the third maintenance action than is flexible pavement.

702.2.6 Whitetopping

Whitetopping is in essence a new concrete pavement built over an existing flexible pavement. It is expected to perform similar to a rigid pavement or an unbonded concrete overlay.

703 Total Cost

Once all the costs for initial construction and future maintenance have been calculated, they are summed to determine the net present value of each alternative. Future maintenance costs are discounted which accounts for and the time value of money.

703.1 Discounting

Discounting is a simple yet effective way to account for the time value of money. The discount rate is essentially the difference between market interest rates and the general rate of inflation. For example, one-year Certificates of Deposit (CD) might be paying 5.5% while inflation is running 2.0% per year, the discount rate would be 3.5%. By the same token, if CD's are paying 8.0% and inflation is running 4.5%, the discount rate is still 3.5%. Using a discount rate thus eliminates the need to predict what inflation will do for the next 35 years or what return one might get on an investment.

The formula for applying the discount rate is as follows:

$$(P/F,i\%,n) = \frac{1}{(1+i)^n}$$

where:

(P/F,i%,n) = discount factor
i = discount rate (0% to 6%)
n = year costs occur

An example showing how to use the discount rate and calculate total cost is given in Figure 703-1.

704 Lane Closure Days

Lane closure days is a measure of the impact of each alternative on the traveling public. It is not a measure of the time needed to construct each alternative. It is merely a comparison tool given a standard work crew, a ten-hour day, a single-lane closure, etc., of how many days it would take to complete each alternative. One lane closure day equals twenty-four hours that a lane is not available to traffic even though work is only being performed for ten hours. The production rates for certain items which can be opened to traffic upon completion of each day's work have been adjusted to account for the fact the lane is not closed twenty-four hours.

The production rates used in calculating the number of days of lane closure are given in Figure 704-1.

705 Results Presentation

A great deal of information is contained in the LCCA and the supporting documentation. It is important it be presented in a standard format. Examples are given in Figures 705-1 and 705-2.

The first page of the report gives general information about the project and the alternatives and provides space for the members of the Pavement Selection Committee to sign off on one alternative. The second page summarizes the District's selected alternative. This page lists each of the principal and secondary factors from the Pavement Design and Selection Process, Appendix A, and gives justification for the selected alternative for each factor. Additional pages may or may not be necessary to give more detailed information on the initial buildups, predicted future maintenance, widening buildups, etc. One page gives background information on the project including historical data on the project, the original construction project, all rehabilitations to date, the existing buildup, etc.; also, the physical attributes such as interchanges, intersections, overhead and at-grade bridges, etc.; and the condition of the existing pavement, PCR, traffic, functional classification, etc. Next are pages showing the details of the LCCA such as items, quantities, prices and costs for initial and future construction. Next, a graph showing how the discount rate affects the apparent least cost alternative and finally a page giving the lane closure analysis.

Once all the information is assembled, the District Deputy Director should sign off on one alternative. The package is then sent to the Pavement Design Section of the Office of Materials Management who will review the LCCA package for concurrence and then forward the report to the Pavement Selection Committee for approval. The Committee will return the signed copy to the Pavement Design Section who will inform the District of the decision and notify FHWA, if necessary.

700 Life-Cycle Cost Analysis

List of Figures

# Discounting Example	**703-1** January 1999
	Reference Section **703.1**

Given:

- Initial Construction (Year 0): $6,500,000
- First Maintenance (Year 12): $800,000
- Second Maintenance (Year 20): $1,600,000
- Third Maintenance (Year 30): $200,000

Problem:

Solve for the net present value using discount rates of 0, 1, 2, 3, 4, 5, and 6%.

Solution:

Calculate the discount factor for each year and discount rate using the equation given in Section 703.1.

Rate	Year 0	Year 12	Year 20	Year 30
0%	1.0000	1.0000	1.0000	1.0000
1%	1.0000	0.8874	0.8195	0.7419
2%	1.0000	0.7885	0.6730	0.5521
3%	1.0000	0.7014	0.5537	0.4120
4%	1.0000	0.6246	0.4564	0.3083
5%	1.0000	0.5568	0.3769	0.2314
6%	1.0000	0.4970	0.3118	0.1741

Multiply costs by discount factors and sum to find Net Present Value (NPV) at each discount rate.

$NPV_{0\%}$ = (6500000)*(1)+(800000)*(1)+(1600000)*(1)+(200000)*(1)
= $9,100,000

$NPV_{1\%}$ = (6500000)*(1)+(800000)*(0.8874)+(1600000)*(0.8195)+(200000)*(0.7419)
= $8,669,500

$NPV_{2\%}$ = (6500000)*(1)+(800000)*(0.7885)+(1600000)*(0.6730)+(200000)*(0.5521)
= $8,318,020

$NPV_{3\%}$ = (6500000)*(1)+(800000)*(0.7014)+(1600000)*(0.5537)+(200000)*(0.4120)
= $8,029,440

$NPV_{4\%}$ = (6500000)*(1)+(800000)*(0.6246)+(1600000)*(0.4564)+(200000)*(0.3083)
= $7,791,580

$NPV_{5\%}$ = (6500000)*(1)+(800000)*(0.5568)+(1600000)*(0.3769)+(200000)*(0.2314)
= $7,594,760

$NPV_{6\%}$ = (6500000)*(1)+(800000)*(0.4970)+(1600000)*(0.3118)+(200000)*(0.1741)
= $7,431,300

Lane Closure Days

704-1
January 1999

Reference Section 704

Item #	Description	ENGLISH Prod. Rate	METRIC Prod. Rate
202	Wearing Course Removed	11,250 SY/Day	9406 m^2/Day
202	Pavement Removed	[1]2250 SY/Day	[1]1881 m^2/Day
202	Base Removed	1000 CY/Day	765 m^3/Day
203	Excavation not Inc. Embankment	2500 CY/Day	1911 m^3/Day
203	Subgrade Compaction	1 Day/Lane	1 Day/Lane
203	Proof Rolling	48,750 SY/Day	40,761 m^2/Day
206	Lime Soil Stabilized Subgrade	2125 SY/Day	1776 m^2/Day
252	Partial Depth Pavement Repair	1625 SY/Day	1359 m^2/Day
252	Rigid Remove/Flexible Replace	1000 SY/Day	836 m^2/Day
252	Pavement Sawing	1 Day/Lane	1 Day/Lane
253	Pavement Repair	875 CY/Day	669 m^3/Day
254	Pavement Planing - Bituminous	[2,3]8750 SY/Day	[2,3]7316 m^2/Day
254	Pavement Planing - PCC	[4]8750 SY/Day	[4]7316 m^2/Day
255	Rigid Remove/Rigid Repl. Class C	[5]875 SY/Day	[5]731 m^2/Day
255	Pavement Sawing	1 Day/Lane	1 Day/Lane
301	Bituminous Aggregate Base (302)	875 CY/Day	669 m^3/Day
304	Aggregate Base	1250 CY/Day	956 m^3/Day
305	Concrete Base	[5]2875 SY/Day	[5]2404 m^2/Day
306	Cement Treated FDB	[6]2875 SY/Day	[6]2404 m^2/Day
307	Non Stabilized Drainage Base	[6]3750 SY/Day	[6]3135 m^2/Day
407	Tack Coat	Neglect	Neglect
408	Bituminous Prime Coat	Neglect	Neglect
409	Seal Coat	Neglect	Neglect
413	Sawing and Sealing	1875 LF/Day	571 m/Day
446-1	AC Surface Course, Type 1	[4,7]1124 CY/Day	[4,7]860 m^3/Day
446-2	AC Intermediate Course, Type 2	[3]625 CY/Day	[3]478 m^3/Day
448-1	AC Surface Course, Type 1	[4,7]1250 CY/Day	[4,7]956 m^3/Day
448-2	AC Intermediate Course, Type 2	[3]688 CY/Day	[3]526 m^3/Day
451 & 452	Concrete Pavement (MAINLINE)	[5]4750 SY/Day	[5]3972 m^2/Day
451 & 452	Concrete Pavement (SHOULDERS)	[5]3175 SY/Day	[5]2655 m^2/Day
453	CRC Pavement	[5]1875 SY/Day	[5]1568 m^2/Day
Special	Asphalt Treated FDB	[6]3125 SY/Day	[6]2612 m^2/Day
Special	Cracking and Seating	12,500 SY/Day	10,451 m^2/Day
Special	Rubblize and Roll	2500 SY/Day	2090 m^2/Day
450...801	Joint Clean/Seal - All Types	[4]13,750 LF/Day + 1 Day/ Lane	[4]4190 m/Day + 1 Day/Lane

Notes to Lane Closure Days

Figure 704-1

1. For situations where shoulders are being removed for replacement, pavement removal and wearing course removal can be done simultaneously. Only use the greater of the two quantities depending on the project

2. On future maintenance only, where planing and a one-course overlay are being performed as one continuous operation, such as thin mill and fill jobs often done as night work, the production rate for this item should be doubled and the time for the overlay neglected.

3. On future maintenance only, where conditions allow the pavement to be opened to traffic at the end of each ten hour work day, the production rate for this item should be doubled. When the dropoff between lanes is too large and the pavement cannot be opened to traffic until the item is completed or other work is being performed which prevents the pavement from being opened, the given production rate should be used with no doubling.

4. Production rates for these items have been adjusted to reflect the fact that the pavement is opened to traffic during the part of the day when work is not being performed.

5. All concrete pavement items do not include the curing time. The curing time should be added to the summary where applicable in the final analysis.
   Class C - 10 Days/Project
   Class MS - 2 Days/Project
   Class FS - 1 Day/Project

6. Where type is yet to be determined, use 3125 SY/Day (2612 m^2/Day).

7. Where Sawing and Sealing is specified, use only 1 Day/Lane for 446-1 or 448-1.

Pavement Type and Rehabilitation Strategy Approval

Project: ABC-1-8.30
Length: 7.84 miles
Plans: 20 % complete

Date: February 29, 1999
PID No.: 12345
Program Amount: $25,000,000

- Alternative 1: Rubblize and Roll - Remove the existing asphalt overlay, rubblize the existing concrete and overlay with 13.5" of asphalt. Twenty-nine percent removal, undercut and replacement is required to meet at-grade bridges and provide clearance at overhead bridges, assuming bridges are not jacked.

- Alternative 2: Unbonded Concrete Overlay - Remove the existing asphalt overlay, place a 1" asphalt bondbreaker layer and overlay with 8" of plain concrete. Twenty-two percent removal, undercut and replacement is required to meet at-grade bridges and provide clearance at overhead bridges, assuming bridges are not jacked.

- Alternative 3: Flexible Replacement - Remove the existing pavement and replace with 12.75" of asphalt on 12" of 304.

- Alternative 4: Rigid Replacement - Remove the existing pavement and replace with 12" of reinforced concrete on a Free Draining Base on 6" of 304.

PLEASE INDICATE BELOW YOUR APPROVAL OF ONE OF THE ALTERNATIVES THEN RETURN TO MATERIALS MANAGEMENT

Pavement Selection Committee	New Design/ Rehabilitation Approval			
	Alt. 1	Alt. 2	Alt. 3	Alt. 4
District Deputy Director				
Assistant Director for Transportation Policy				
Assistant Director for Field Operations				
Deputy Director of Engineering Policy				

Selection Summary Sheet

Alternative 2, Unbonded Concrete Overlay, has been selected by the District. The following discussion concerning this selection is provided in an effort to communicate the rational for this decision.

Principal Factors

LCCA: The Unbonded Concrete Overlay has the lowest life-cycle cost for discount rates between zero and three percent. Above approximately 3.5%, Alternative 3, Flexible Replacement, has the lowest life-cycle cost, however, even at a 6% discount rate, the Unbonded Concrete Overlay is less than 5% more than the Flexible replacement. Differences of five to ten percent between alternatives are considered insignificant for most life-cycle cost analyses.

Initial Cost: The Flexible Replacement has the lowest initial cost and none of the other alternatives are within five percent. The Unbonded Concrete Overlay is more than ten percent greater than the Flexible, however, given its other advantages, District felt the additional initial cost was justified.

User Delay: The Unbonded Concrete Overlay has the fewest days of lane closure.

Municipal Preference: This project is rural and is not located within any municipality.

Secondary Factors

Geometrics: This project, classified as hilly terrain, includes three locations where grade is in excess of 3%. The District has had problems in the past with rutting where 1% to 2% grades are present for bridge embankments. Based on our desire to reduce maintenance required on the pavement, the Unbonded Concrete Overlay is preferred. The life-cycle cost analysis did not account for any additional costs which might be associated with the use of special rut-resistant asphalt mixes.

Constructability: Due to the widening, all of the alternatives could be constructed without crossing traffic over, however, part-width construction is not recommended with free draining bases. Since there are no interchanges on this project, traffic could easily be crossed over to allow the contractor full access to one side. We see no major advantages or disadvantages regarding constructability/maintenance of traffic for any of the alternatives.

Availability of Local Materials: Our District finds it difficult to find quality aggregates for both asphalt and concrete. We see no real advantage for any alternative.

Other Issues: Our District has had very good performance with unbonded concrete overlays in the past.

Initial Construction Designs

Alternative 1: Rubblize and Roll

1.5"	446	Asphalt Concrete Surface Course, Type 1H
	407	Tack Coat for Intermediate Course
1.75"	446	Asphalt Concrete Intermediate Course, Type 2
10.5"	302	Bituminous Aggregate Base
	Special	Rubblize and Roll Existing Reinforced Concrete Pavement

Alternative 2: Unbonded Concrete Overlay

8"	452	Plain Concrete Pavement
1"	448	Asphalt Concrete Intermediate Course, Type 1

Alternative 3: Flexible Replacement

1.5"	446	Asphalt Concrete Surface Course, Type 1H
	407	Tack Coat for Intermediate Course
1.75"	446	Asphalt Concrete Intermediate Course, Type 2
9.5"	302	Bituminous Aggregate Base
12"	304	Aggregate Base

Alternative 4: Rigid Replacement

12"	451	Reinforced Concrete Pavement	
	Special	Free Draining Base	
	408	Bituminous Prime Coat	
6"		304	Aggregate Base

Widening Buildups

Alternative 1: Rubblize and Roll

1.5"	446	Asphalt Concrete Surface Course, Type 1H
	407	Tack Coat for Intermediate Course
1.75"	446	Asphalt Concrete Intermediate Course, Type 2
10.5"	302	Bituminous Aggregate Base
12"	304	Aggregate Base

Alternative 2: Unbonded Concrete Overlay

12"	452	Plain Concrete Pavement
13"	304	Aggregate Base

Anticipated Future Maintenance

Alternative 1: Rubblize and Roll

@ 12 years:	1.5" mill and fill
@ 20 years:	4" overlay with milling
@ 30 years:	1.5" mill and fill

Alternative 2: Unbonded Concrete Overlay

@ 25 years	Repair 5% of the pavement, grind for smoothness and reseal joints

Alternative 3: Flexible Replacement

@ 15 years:	2" mill and fill
@ 25 years:	4" overlay with milling

Alternative 4: Rigid Replacement

@ 25 years:	Repair 5% of the pavement, grind for smoothness and reseal joints

Project Summary

- **Historical Data**

Project Numbers	530(57)
	557(57)
SLM	8.30
Project Length	7.84 miles
Pavement Buildup	5.25" Asphalt
	10" Reinforced Concrete
	6" Subbase
Joint Spacing	60'
Drainage	Pipe Underdrains
Rehabilitations to date	571(72)
	159(86)

- **Physical Attributes**

Signalized Intersections	None
Interchanges	None
Overhead Structures	Five
<u>Structure</u>	<u>Clearance</u>
0844	16'-3" Δ 15'-1"
0995	14'-11" Δ 15'-3"
1111	14'-8" Δ 15'-0"
1268	14'-0" Δ 15'-7"
1559	19'-1" Δ 14'-10"
At-Grade Structures	Three Sets

- **Project Evaluation**

Overall Condition	Fair to Poor
PCR/Structural Deduct	59/21
20-year Design ESAL's	65.5 million (Rigid)
	47.4 million (Flexible)
ADT (1994)	25390
% Trucks (1994)	34%
Functional Classification	Rural Interstate

Initial Construction				Quantities			
ITEM	DESCRIPTION	UNIT	AMT.	Alt. 1	Alt. 2	Alt. 3	Alt. 4
202	Pavement Removed	SY		62,400	49,067		
202	Pavement Removed	SY				218,293	218,293
202	Wearing Course Rem.	SY		220,849	239,738		
203	Excavation	CY		237,668	190,709	215,767	196,060
203	Subgrade Compaction	SY		324,884	305,996		
203	Subgrade Compaction	SY				545,733	545,733
302	Bit. Aggregate Base	CY	9.5			144,013	
302	Bit. Aggregate Base	CY	10.5	90,861			
302	Bit. Aggregate Base	CY	14.5	132,034			
304	Aggregate Base	CY	6				90,956
304	Aggregate Base	CY	12	112,193			
304	Aggregate Base	CY	12			181,911	
304	Aggregate Base	CY	13		112,510		
407	Tack Coat	Gal		40,930		40,930	
408	Bituminous Prime Coat	Gal					218,293
446	AC Surface, Type 1	CY	1.5	22,739		22,739	
446	AC Intermediate, Type 2	CY	1.75	26,529		26,529	
448	AC Intermediate, Type 1	CY	1		15,159		
452	Plain Concrete Pavem't	SY	8		239,738		
452	Plain Concrete Pavem't	SY	12		305,996		545,733
Special	Rubblize and Roll	SY		155,893			
Special	Free Draining Base	SY					545,733

Future Maintenance				Quantities			
ITEM	DESCRIPTION	UNIT	AMT.	Alt. 1	Alt. 2	Alt. 3	Alt. 4
	@ 12 Years						
254	Pavement Planing	SY		545,733			
254	Patching Planed Surface	SY	3%	16,372			
407	Tack Coat	Gal		40,930			
446	AC Surface, Type 1	CY	1.5	22,739			
	@ 15 Years						
254	Pavement Planing	SY				545,733	
254	Patching Planed Surface	SY	3%			16,372	
407	Tack Coat	Gal				40,930	
446	AC Surface, Type 1	CY	2			30,319	
	@ 20 Years						
254	Pavement Planing	SY		545,733			
254	Patching Planed Surface	SY	3%	16,372			
407	Tack Coat	Gal		81,860			
446	AC Surface, Type 1	CY	1.5	22,739			
446	AC Intermediate, Type 2	CY	2.5	37,898			
	@ 25 Years						
254	Pavement Planing	SY				545,733	
254	Patching Planed Surface	SY	3%			16,372	
255	Rigid Repairs	SY	5%		16,372		16,327
255	Pavement Sawing	LF			73,674		73,674
407	Tack Coat	Gal				81,860	
446	AC Surface, Type 1	CY	1.5			22,739	
446	AC Intermediate, Type 2	CY	2.5			37,898	
801	Longit. Joint Sealing	LF			327,440		327,440
801	Trans. Joint Sealing	LF			313,476		313,476
Special	Diamond Grinding	SY			327,440		327,440
	@ 30 Years						
254	Pavement Planing	SY		545,733			
254	Patching Planed Surface	SY	3%	16,372			
407	Tack Coat	Gal		40,930			
446	AC Surface, Type 1	CY	1.5	22,739			

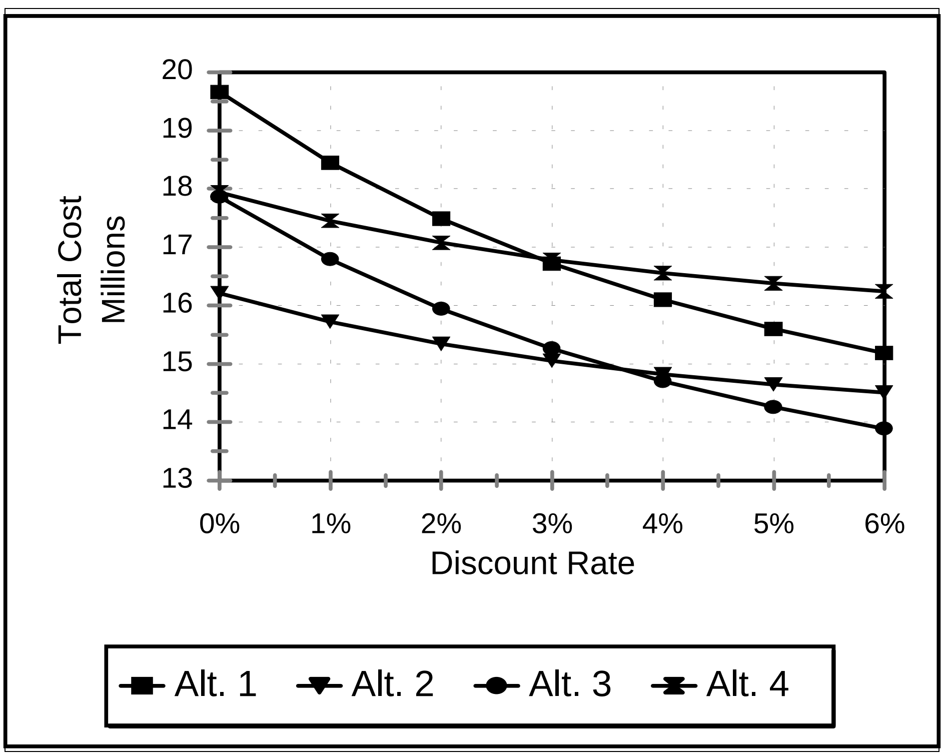
Initial Construction		Price	Costs			
ITEM	DESCRIPTION		Alt. 1	Alt. 2	Alt. 3	Alt. 4
202	Pavement Removed	$4.74	$295,776	$232,576		
202	Pavement Removed	$4.00			$873,173	$873,173
202	Wearing Course Rem.	$0.75	$165,637	$179,803		
203	Excavation	$2.11	$501,480	$402,397	$455,268	$413,686
203	Subgrade Compaction	$0.55	$178,686	$168,298		
203	Subgrade Compaction	$0.50			$272,867	$272,867
302	Bit. Aggregate Base	$32.41			$4,667,460	
302	Bit. Aggregate Base	$32.12	$2,918,449			
302	Bit. Aggregate Base	$32.12	$4,240,929			
304	Aggregate Base	$20.00				$1,819,111
304	Aggregate Base	$20.00	$2,243,867			
304	Aggregate Base	$18.00			$3,274,400	
304	Aggregate Base	$20.00		$2,250,196		
407	Tack Coat	$0.77	$31,516		$31,516	
408	Bituminous Prime Coat	$0.70				$152,805
446	AC Surface, Type 1	$60.00	$1,364,333		$1,364,333	
446	AC Intermediate, Type 2	$42.49	$1,127,205		$1,127,205	
448	AC Intermediate, Type 1	$37.00		$560,893		
452	Plain Concrete Pavement	$18.00		$4,315,280		
452	Plain Concrete Pavement	$20.00		$6,119,911		$10,914,667
Special	Rubblize and Roll	$1.77	$275,931			
Special	Free Draining Base	$2.35				$1,282,473
	Total Initial Construction		**$13,048,034**	**$13,996,777**	**$12,066,222**	**$15,728,783**

Future Maintenance		Price	Costs			
ITEM	DESCRIPTION		Alt. 1	Alt. 2	Alt. 3	Alt. 4
	@ 12 Years					
254	Pavement Planing	$0.55	$300,153			
254	Patching Planed Surface	$0.40	$6,549			
407	Tack Coat	$0.77	$31,516			
446	AC Surface, Type 1	$60.00	$1,364,333			
	@ 15 Years					
254	Pavement Planing	$0.55			$300,153	
254	Patching Planed Surface	$0.40			$6,549	
407	Tack Coat	$0.77			$31,516	
446	AC Surface, Type 1	$60.00			$1,819,111	
	@ 20 Years					
254	Pavement Planing	$0.55	$300,153			
254	Patching Planed Surface	$0.40	$6,549			
407	Tack Coat	$0.77	$35,200			
446	AC Surface, Type 1	$60.00	$1,364,333			
446	AC Intermediate, Type 2	$39.67	$1,503,420			
	@ 25 Years					
254	Pavement Planing	$0.55			$300,153	
254	Patching Planed Surface	$0.40			$6,549	
255	Rigid Repairs	$45.00		$736,740		$736,740
255	Pavement Sawing	$1.42		$104,617		$104,617
407	Tack Coat	$0.43			$35,200	
446	AC Surface, Type 1	$60.00			$1,364,333	
446	AC Intermediate, Type 2	$39.67			$1,503,420	
801	Longit. Joint Sealing	$1.00		$327,440		$327,440
801	Trans. Joint Sealing	$1.25		$391,845		$391,845
Special	Diamond Grinding	$2.00		$654,880		$654,880
	@ 30 Years					
254	Pavement Planing	$0.55	$300,153			
254	Patching Planed Surface	$0.40	$6,549			
407	Tack Coat	$0.77	$31,516			
446	AC Surface, Type 1	$60.00	$1,364,333			
		Total Future Maintenance	**$6,614,758**	**$2,215,522**	**$5,799,023**	**$2,215,522**
		Total Cost of Alternative	**$19,662,792**	**$16,212,299**	**$17,865,245**	**$17,944,304**

Sensitivity Analysis of the Discount Rate

The Discount Rate is a tool used in evaluating the time value of money. It is broadly defined as the difference between market interest rates and inflation. Because costs are incurred at different points in time over the life of a pavement, the discount rate is used to compare these costs in terms of constant dollars. In this case, 1998 dollars have been used as constant dollars. A survey of states done in the mid 1990's indicated the range of discount rates used throughout the country varies from 0% to 7%. The most common rate used was 4%. Rather than using just one discount rate, a range of rates has been used to show how different rates affect the apparent least cost alternative.

Rate	Alt. 1	Alt. 2	Alt. 3	Alt. 4
0%	$19,662,792	$16,212,299	$17,868,929	$17,944,304
1%	$18,452,579	$15,724,371	$16,802,534	$17,456,376
2%	$17,490,419	$15,347,206	$15,949,282	$17,079,211
3%	$16,720,706	$15,054,922	$15,263,552	$16,786,928
4%	$16,101,215	$14,827,856	$14,710,047	$16,559,862
5%	$15,599,695	$14,651,027	$14,261,344	$16,383,032
6%	$15,191,367	$14,515,990	$13,896,057	$16,244,996



Lane Closure Summary*

Action	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Initial Construction	614	381	562	577
Future Maintenance				
@ 12 Years	31			
@ 15 Years			31	
@ 20 Years	143			
@ 25 Years		119	143	119
@ 30 Years	31			
Total of Future	205	119	174	119
Total No. of Days	**819**	**500**	**736**	**696**

* Lane Closure Summary is for comparison purposes only and is not an estimate of the actual time for construction as many factors exist which were not considered.

New Pavement Type Approval

Project: XYZ-999-2.66
Length: 4.48 miles
Plans: 10% complete

Date: February 29, 1999
PID No.: 98765
Program Amount: $15,000,000

! Flexible Alternative:

1.5"	446	Asphalt Concrete Surface Course, Type 1H
1.75"	446	Asphalt Concrete Intermediate Course, Type 2
7.5"	302	Bituminous Aggregate Base
	307	Non-Stabilized Drainage Base Type IA or NJ
	408	Bituminous Prime Coat
6"	304	Aggregate Base

Anticipated Future Maintenance
@ 12 Years: Mill and fill mainline only with 1.5 inches
@ 22 Years: Repair 1% of the pavement, mill and overlay with 4 inches

! Rigid Alternative:

10"	452	Plain Concrete Pavement
	307	Non-Stabilized Drainage Base Type IA
	408	Bituminous Prime Coat
6"	304	Aggregate Base

Anticipated Future Maintenance
@ 22 Years: Repair 2% full depth and 1% partial depth and grind for smoothness

PLEASE INDICATE BELOW YOUR APPROVAL OF ONE OF THE ALTERNATIVES THEN RETURN TO MATERIALS MANAGEMENT

Pavement Selection Committee	New Design Approval: Flexible	New Design Approval: Rigid
District Deputy Director		
Assistant Director for Transportation Policy		
Assistant Director for Field Operations		
Deputy Director of Engineering Policy		

Selection Summary Sheet

The Flexible Alternative has been selected by the District. The following discussion concerning this selection is provided in an effort to communicate the rational for this decision.

Principal Factors

<u>LCCA:</u> The Flexible Alternative has the lowest life-cycle cost at all discount rates although the Rigid Alternative is within 5% of it at zero percent discount rate.

<u>Initial Cost:</u> The Flexible Alternative has the lowest initial cost and the Rigid Alternative is more than 10% greater.

<u>User Delay:</u> The Flexible Alternative has almost twice as many days of lane closure as the Rigid Alternative. This project is located in a rural area with low ADT however, and we don't feel the lane closures will cause any backups or significant disruption to the traveling public and the other factors in favor of the Flexible Alternative outweigh this drawback.

<u>Municipal Preference:</u> This project is rural and not located within any municipality.

Secondary Factors

<u>Geometrics:</u> This project is located on flat terrain with very little grade. There are no geometric constraints which would favor either alternative.

<u>Constructability:</u> This project is new pavement on new alignment and any pavement can be constructed easily.

<u>Availability of Local Materials:</u> There are currently no available aggregate sources nearby for coarse aggregates which have passed the D-cracking test required for concrete.

<u>Other Issues:</u> Our District has had very good performance with flexible pavement the past.

Project Summary

20-year Design ESAL's	24.7 million (Rigid) 16.7 million (Flexible)
ADT (1997)	8430
% Trucks (1997)	12 %
Functional Classification	Rural Principle Arterial

Days of Lane Closure*

Action	Flexible	Rigid
Initial Construction	(Not applicable, new location)	
Future Maintenance		
@ 12 Years	7	
@ 22 Years	53	34
Total of Future Maint.	60	34
Total No. of Days	**60**	**34**

* Lane Closure summary is for comparison purposes only and is not an estimate of the actual time for construction as many factors exist which were not considered.

Initial Construction				Quantities		Costs		
Item	Description	Unit	Amt.	Flexible	Rigid	Price	Flexible	Rigid
203	Subgrade Compaction	SY		199,748	199,748	$0.58	$115,854	$115,854
302	Bituminous Aggregate Base	CY	7.5	42,709		$44.00	$1,879,211	
304	Aggregate Base	CY	6	35,044	34,167	$21.10	$739,419	$720,934
307	Non-Stabilized DB	SY		199,748	199,748	$3.17	$633,202	$633,202
407	Tack Coat for Intermediate	Gal		14,981		$0.65	$9,738	
408	Prime Coat	Gal		79,899	79,899	$0.84	$67,115	$67,115
446	AC Surface, Type 1H	CY	1.5	8,323		$68.15	$567,202	
446	AC Intermediate, Type 2	CY	1.75	9,710		$43.47	$422,093	
452	Plain Concrete	SY	10		199,748	$21.00		$4,194,714
						Total Cost of Initial Construction	**$4,433,834**	**$5,731,819**

Future Maintenance				Quantities		Costs		
Item	Description	Unit	Amt.	Flexible	Rigid	Price	Flexible	Rigid
	@ 12 Years							
254	Pavement Planing	SY		126,157		$0.59	$74,433	
254	Patching Planed Surface	SY		1,262		$2.95	$3,722	
407	Tack Coat	Gal		9,462		$0.71	$6,718	
446	AC Surface, Type 1H	CY	1.5	5,257		$68.15	$358,233	
	@ 22 Years							
253	Pavement Repair	SY	0.5%	631		$85.97	$54,229	
254	Pavement Planing	SY		199,748		$0.59	$117,851	
254	Patching Planed Surface	SY		1,997		$2.95	$5,893	
407	Tack Coat	Gal		14,981		$0.65	$9,738	
407	Tack Coat for Intermediate	Gal		14,981		$0.65	$9,738	
446	AC Surface, Type 1H	CY	1.5	8,323		$68.15	$567,202	
446	AC Intermediate, Type 2	CY	2.5	13,871		$43.47	$602,990	
	@ 22 Years							
255	Rigid Repairs	SY	2%		2,523	$56.28		$142,002
255	Pavement Sawing	LF			11,354	$2.17		$24,638
256	Bonded Patching	SF	1%		11,354	$30.00		$340,623
Spec.	Diamond Grinding	SY			126,157	$2.44		$307,823
						Total Cost of Future Maintenance	**$1,810,745**	**$815,086**
						Total Cost of Alternative	**$6,244,578**	**$6,546,905**

Sensitivity Analysis of the Discount Rate

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Discount Rate	Flexible	Rigid
0%	$6,244,578	$6,546,905
1%	$5,925,832	$6,386,656
2%	$5,667,862	$6,259,048
3%	$5,458,380	$6,157,206
4%	$5,287,679	$6,075,749
5%	$5,148,099	$6,010,456
6%	$5,033,570	$5,958,009