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Life Cycle Cost Analysis State-of-the-Practice

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DEPARTMENT OF TRANSPORTATION

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The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The report provides details regarding the recommended practice from the Materials Advisory Committee for the Colorado Department of Transportation when performing a Life Cycle Cost Analysis. However, it does not constitute a standard, specification, or regulation.

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16. Abstract

This report provides an outline for the engineer seeking to conduct a Life-Cycle Cost Analysis (LCCA) in pavement design and selection. The guidance, recommendations, and default values provided here were collected from 10 years of paving projects. Most of these projects were constructed or rehabilitated in the mid 1980's in order to evaluate the current design and construction practices in the State of Colorado. At this time, CDOT uses a deterministic approach to the LCCA and is researching the move toward a probabilisitc LCCA.

Implementation

It is recommended that this report be used as a guide in the pavement design and selection until data can be collected and evaluated on asphalt pavements designed and constructed using the Supepave™ technology.

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INTRODUCTION

There has been great concern in recent years over the cost of highway construction, maintenance, and rehabilitation. It is essential to make economically sound decisions concerning proposed expenditures of taxpayer’s resources to ensure that the most cost-effective alternatives are selected. In the past, selections were often made by comparing the initial cost of one type of pavement to another. In order to emphasize the need for a complete cost analysis; the term “life-cycle costs” was coined in approximately 1970 for use with pavements.

In general, life-cycle costs refer to all costs that are anticipated for the life of the facility. The analysis includes identifying and evaluating the economic consequences of various alternatives either over time or over the life cycle of the pavement. These include costs such as design, construction, maintenance, rehabilitation, user, and salvage, which are converted into today’s dollar value through a discounted cash-flow analysis.

There are several different economic analytical methods that have been used for comparing alternatives. The method most often used by other agencies and the method used by the Colorado Department of Transportation (CDOT) is the Present Worth or Present Value Method.

DEFINITIONS

The following definitions have been simplified, in some cases, for use on pavement projects.

Analysis Period. The analysis period is the time period used for comparing various design alternatives. According to the Federal Highway Administration (FHWA), the analysis period must contain at least one rehabilitation activity, but may or may not contain maintenance activities during the life cycle of the evaluated pavement. *National Cooperative Highway Research Program* (NCHRP) Report 122 recommends that the analysis period for comparing new design alternatives should be 25 to 40 years. This is considered sufficient time for predicting future costs in order to capture the most significant costs. Since CDOT will be using the NPV "Net Present Value" method (described on the bottom of Page 3), the analysis period must be the same when comparing alternatives. CDOT will use a 30-year analysis period.

Constant dollars. Constant dollars are uninflated and represent the prevailing price for all elements at the base year for the analysis.

Current dollars. Current dollars are inflated and represent the price levels that may exist at some future date when costs are incurred. The uncertainty associated with predicting future rates of inflation, and incorporating price changes into the economic analysis, is extremely complex. Because of this, CDOT follows the generally accepted approach of using constant dollars and a discount rate.

Design Life. Periods of time, in years, for which the volume and type of traffic and the resultant wheel or axle load application, are forecast, and on which the pavement designs are calculated.

Discount rates. A value in percent used for comparing the alternative uses of funds over a period of time. In a report entitled *Economic Analysis of Airport Pavement Rehabilitation Alternatives – An Engineering Manual*,[(1)] there is general agreement that the discount rate should be the difference between the market interest rate and inflation using "constant" dollars over the analysis period. The Office of Management and Budget (OMB) defined the real discount rate as the "actual yield" on a 10-year Treasury note to an investor after inflation. For a 30-year maturity, the OMB published Circular A-94 that showed that real discount rates for the past six years ranged from 3 to 4.9% with an average of 4.0%. The American Association of State Transportation Officials (AASHTO) in a 1977 report entitled, *A Manual on User Benefits Analysis and Bus Transit Improvement* states, "… a rate of about 4 to 5% seems appropriate for projects of average risk evaluated in constant dollars." CDOT, therefore, has chosen to use a 4% discount rate using constant dollars.

Initial Costs. The total investment required by CDOT to prepare a highway improvement for service. The initial cost will include the estimated cost of pavement construction and may include other costs such as preliminary engineering, traffic control, and construction engineering. The construction costs used in the analysis should be the most current and accurate data available. If other costs for the same project elements are identical, it should be noted in the report and not included in the analysis.

Maintenance Costs. The cost of preserving an existing pavement and keeping the roadway as safe as possible.

Present Value (PV). The PV method involves the conversion of all present and future expenses to a base of today's costs. The present worth of planned future funds is equivalent to the amount of money needed to be invested now at a given compound interest rate for the original investment plus interest to equal the expected cost at the time needed. The PV equation for nonrecurring costs is:

$$PV = F \times \frac{1}{(1+i)^n}$$

Where

F = The future sum of money at the end of n years from now.
n = Number of years
i = Discount rate

Example, for $5,000 at a 4% discount rate to be used 20 years into the future the PV is $2,282.

The PV equation for recurring (annual) costs is:

$$PV = A \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

Where

A = End-of-year payments (annual payments)
n = Number of years
i = Discount rate

Example, for a $1,000 annual cost for 10 years at a 4% discount rate the PV is $8,111.

The term, NPV refers to the net cumulative present value of a series of costs over the analysis period.

Rehabilitation Costs. The cost for the activities associated with restoring or resurfacing the pavement to an acceptable level of service.

Running Cost. The mileage-dependent cost of driving cars, trucks, and other motor vehicles on the highway. This includes the expense of fuel, oil, tires, maintenance, and vehicle depreciation attributable to highway miles.

Salvage Value. The salvage value is the residual value of the pavement at the end of the life-cycle analysis period. CDOT has concluded that the difference in value between alternatives at the end of the analysis period is minimal when calculated in present dollars. Example: If the difference between alternatives was $100,000 at the end of the 30-year analysis period, using a discount rate of 4% the NPV is $30,831. Therefore CDOT will not use salvage value in the pavement analysis.

Traffic Accident Costs. The cost attributed to motor vehicle traffic accidents. Due to the lack of appropriate cost data and accident history in a work zone, CDOT will not include the cost of accidents in the analysis.

Useful Life. The number of years that a component will last before it needs to be replaced or upgraded.

User Costs. Indirect or nonagency (soft) costs which are accrued by the road user. These costs should include delays associated with using a vehicle and the value of vehicle user travel time.

Unit Value of Time. The cost of time attributed to one hour of travel, which is usually different for cars and trucks.

Value of Travel Time. Vehicle travel time multiplied by the average unit value of time.

Vehicle Travel Time. The total hours traveled by a specific vehicle.

CDOT COST FACTORS

The cost factors are values associated with the life-cycle cost analysis (LCCA) that cover the full cycle from the initial design to the end of the analysis period. Since approximately 1990, CDOT has been performing the LCCA and has tracked many of the cost factors. Some of the factors engineers should determine include:

1. Design Costs – The expected preliminary engineering (PE) costs for designing a new or rehabilitated pavement including materials, site investigation, traffic analysis, pavement design, and preparing plans with specifications. The PE costs vary from region to region and are in the range of 8 to 12% with the average being 10% of the total project cost.
2. Construction Costs – The costs to build a section of pavement in accordance with the plans and specifications. The construction cost is one of the most important in the LCCA and should be as accurate as possible. The current version of CDOT's Cost Data manual should be used unless up-to-date bid prices are available for similar work in the same general area. If there is a wide range of prices for a certain item, then it is best to run a sensitivity analysis to determine the effect of cost variation on the end result. Included in the construction cost should be the cost of engineering (CE). The CE cost for CDOT is currently 12% of the total project cost.
3. Traffic Control Costs – The cost to place and maintain signs, signals, and markings and devices placed on the roadway to regulate, warn, or guide traffic. In some designs, the construction traffic control costs may be the same in both alternatives and excluded from the LCCA.
4. Maintenance Costs – The costs associated with maintaining a pavement at an acceptable performance level. A LCCA task force was formed in May 1998 to compile data from the Maintenance Management System (MMS). This report summarized 10 years of the annual maintenance costs of 39-flexible and 33-rigid pavement sections throughout the state. All pavement sections had a 20-year design life and most projects were placed in service within the last 20 years. The average year that the flexible sections

were placed in service was 1984; the rigid sections were placed in 1985. The values in Table 1 are rounded to the nearest $50 and include all annual maintenance costs associated with patching, crack and joint sealing, planing, and fog and seal coating. The yearly maintenance costs for each pavement section are summarized in Appendix A. Use these numbers in Table 1 as default values. If exact data is required, the engineer should contact their local MMS coordinator for information on segments near the pavement to be constructed.

Table 1

Annual Maintenance Costs

Region	Type of Pavement	Average annual cost Per lane mile	Standard Deviation	Lane Miles surveyed
1	HBP	1600	1050	64
	PCCP	50	50	438
2	HBP	650	450	118
	PCCP	0	N/A	54
3	HBP	950	550	86
	PCCP	100	N/A	42
4	HBP	1000	900	62
	PCCP	200	150	930
5	HBP	2700	2900	36
	PCCP	100	100	32
6	HBP	1450	950	47
	PCCP	150	200	195
Statewide	HBP	1300	1250	413
	PCCP	150	150	1691

5. Rehabilitation costs – These costs cover activities performed as part of rehabilitating or restoring pavement. They also represent periodic costs at future dates used to restore the pavement to an acceptable performance level. The default values normally used for the rehabilitation costs should be based on the rehabilitation strategies of what has historically been accomplished.

For CDOT projects, we recommend the following default values be used for rehabilitation costs;

- $ 52.00/ton for Superpave Hot Bituminous Pavement (HBP).
- $ 65.00/ton for Stone Mastic Asphalt pavement.
- $ 1.00/yd^2 for rotomilling HBP.
- $ 6.50/yd^2-inch for slab replacement of Portland Cement Concrete Pavement (PCCP).
- $ 5.00/yd^2 for diamond grinding ¼ inch of PCCP.

6. *User costs* – These costs are considered to be indirect "soft" costs accumulated by the facility user in the work zone as they relate to roadway condition, maintenance activity, and rehabilitation work over the analysis period. For example, these costs include user travel time, increased vehicle operating costs (VOC), and crashes. Though these "soft" costs are not part of the actual spending for CDOT, they are costs borne by the road user and should be included in the LCCA. Due to the lack of crash cost data for certain types of work zone activities, CDOT will not consider the costs due to crashes.

   VOC rates for stopping, speed change, idling, and delay times can be found in NCHRP report 133, table 5, and are reproduced in Table 2. This table has been updated to costs for June 1999.

Table 2. Added Time and Vehicle Running Cost / 1000 Stops and Idling Cost (June 99).

Initial Speed (mph)	Added Time (Hr / 1000 Stops) (Excludes Idling Time)			Added Cost ($/1000 Stops) (Excludes Idling Time)		
	Pass Cars	Single Unit Truck	Combination Truck	Pass Cars	Single Unit Truck	Combination Truck
5	1.02	0.73	1.10	2.71	9.29	33.76
10	1.51	1.47	2.27	8.87	20.80	77.82
15	2.00	2.20	3.48	15.22	34.03	130.51
20	2.49	2.93	4.76	21.83	48.60	190.85
25	2.98	3.67	6.10	28.79	64.24	257.62
30	3.46	4.40	7.56	36.25	80.57	329.59
35	3.94	5.13	9.19	44.24	97.28	405.54
40	4.42	5.87	11.09	52.92	114.45	484.23
45	4.90	6.60	13.39	62.33	130.63	564.50
50	5.37	7.33	16.37	72.62	146.57	645.11
55	5.84	8.07	20.72	83.82	161.56	724.80
60	6.31	8.80	27.94	96.10	179.73	802.35
65	6.78	9.53	NA*	109.48	196.67	NA*
70	7.25	NA*	NA*	124.13	NA*	NA*
75	7.71	NA*	NA*	140.11	NA*	NA*
80	8.17	NA*	NA*	157.51	NA*	NA*
Idling Cost ($ / vehicle-hr)				0.6944	0.7713	0.8283

* Original data did not provide values for trucks at higher speeds. The engineer will need to extrapolate these values when truck calculations are needed at these higher speeds.

The added cost ($/1000 Stops) includes fuel, tires, engine oil, maintenance, and depreciation. The idling cost ($/Veh-Hr) includes fuel, engine oil, maintenance, and depreciation. To make the added cost factors shown in Table 2 applicable to current day analysis, the values shown have been increased to reflect current (known as “escalation”) dollars. The escalation factor for VOC is found by using the unadjusted U.S. city annual average of the transportation component in the Consumer Price Index (CPI) for all urban consumers in the base period (1970) and the current year (June 1999). The current CPI can be found on the Internet at http://www.bls.gov/news.release/cpi.t01.htm. The transportation component of the CPI was 37.5 in base period 1970 and 143.4 in June 1999.

$$\text{Escalation Factor (VOC)} = \frac{143.4 \text{ (June 1999)}}{37.5 \text{ (1970)}} = 3.824$$

While Table 2 is designed to determine stopping costs, it can also be used to figure speed change costs. Speed change costs are the additional costs (VOC and delay) of slowing from one speed to another, then returning to the original speed. Speed change costs are calculated by subtracting the cost and time factors of stopping at one speed from the cost and time factors of stopping at another speed. For example, the speed change cost of going from 60 mph to 40 mph and back to 60 mph is shown in Table 2.1.

Table 2.1 Speed Change Computations.

Initial Speed (mph)	Added Time (Hr / 1000 Stops) (Excludes Idling Time)			Added Cost ($/1000 Stops) (Excludes Idling Time)		
	Pass Cars	Single Unit Truck	Combination Truck	Pass Cars	Single Unit Truck	Combination Truck
60	6.31	8.80	27.94	96.10	179.73	802.35
40	4.42	5.87	11.09	52.92	114.45	484.23
60-40-60	1.89	2.93	16.85	43.18	65.28	318.12

Table 2.2 reflects the value of time for user delay per vehicle. They are recommended for use in a typical analysis where distribution data on trip purpose and type are not known. These figures are based on the May 1998 Bureau of Labor Statistics report on the National Compensation Survey for the Denver-Boulder-Greeley region. Current information on wage rates can be found on the Internet at http://www.bls.gov/comhome.htm. CDOT is recommending default values of $17.00 for passenger cars, $35.00 for single unit trucks, and $36.50 for combination trucks. A multiplier was adopted to include incidentals such as fringe benefits, overhead, and profit. The range of the values for the multiplier was from 2.1 to 3.0 with a value of 2.5 used. Based on a number of surveys regarding wages for truck drivers, the average hourly rate for a combination truck driver was higher than that of a single unit

driver. The difference between the two ranged from 1.7 to 7.7% with an average value of 4.0% used in the valuation.

Table 2.2 Recommended Values of Travel Time $/Vehicle Hour (May 1998).

	Mean wages of all occupations (Passenger Cars)	Mean wages of transportation and material moving occupations (Truckers)	
		Single Unit	Combinations
Hourly Wage Rate	$ 16.99	$13.99	$13.99 x 1.04 = $14.55
Multiplier	N/A	2.5	2.5
	$16.99 use $17.00	$34.98 use $35.00	$36.37 use $36.50

The work zone user costs equal the increased VOC and delay costs that result from construction, maintenance, or rehabilitation of the highway. CDOT will figure the user costs for construction and rehabilitation, but not determine the user costs associated with maintenance activities. The user costs are a function of a number of factors including timing, duration, frequency, scope, and characteristics of the work zone. They also include the volume and operating characteristics of the traffic affected along with the dollar rates assigned to the VOC and delay costs.

REHABILITATION CYCLES

Based on data from 24 rigid pavement projects, constructed throughout the state, pavements with a design life of 20 years should have a two-inch HBP overlay placed in the 22nd year of service. This information can be found in Appendix B. For rigid pavements with a design life of 30 years, the following treatment is recommended. Increase the initial design thickness by ¼ inch, so that by year 20, the ¼ inch diamond grinding of the surface can be performed along with 1% slab replacement.

Based on six years of performance data and overlay history dating back to 1976 for 17 flexible pavement projects constructed on the National Highway System (NHS) and 15 project not on the NHS with a design life of 20-years, the following treatment is recommended. A two-inch HBP overlay should be placed at years 8, 16, and 23 for projects constructed on the NHS. For projects not constructed on the NHS, it is also recommended that the two-inch overlay be completed in the 10^{th} and 20^{th} year of service. Historical data for 32 HBP projects constructed throughout the state can be found in Appendix C.

MICROCOMPUTER PROGRAMS

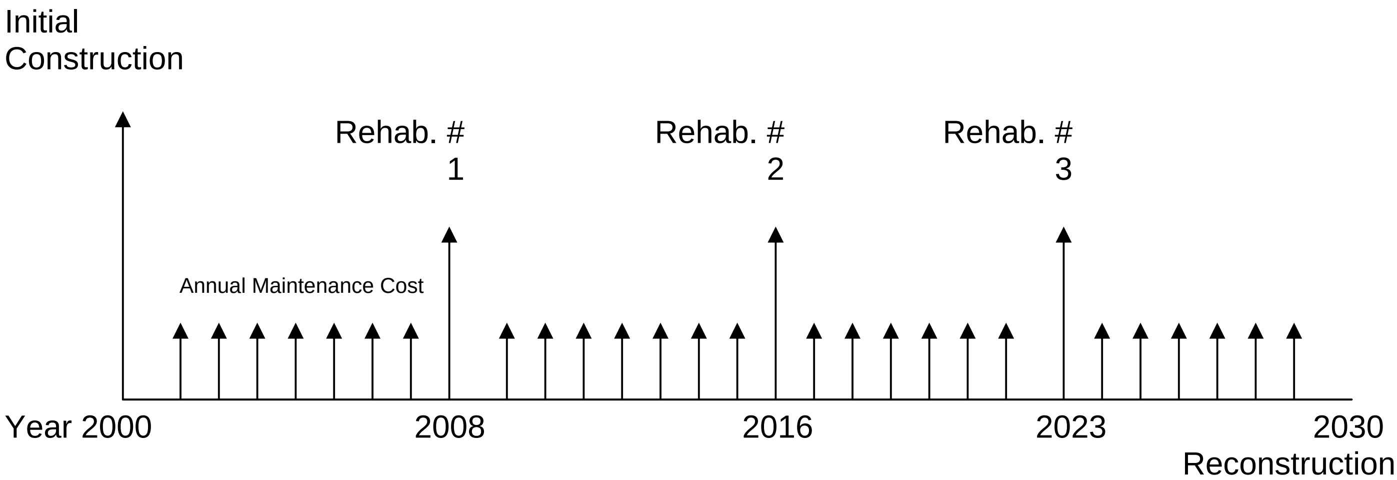
There are many computer software programs available to help designers solve basic LCCA's and generate multiple design strategies to achieve optimum economical solutions. CDOT recommends the use of the LCCA module in the AASHTO pavement design software, DARWin®.

Based upon a report entitled *User Cost Models for Pavement Maintenance and Rehabilitation Alternatives in Highway Work Zones,* [(2)] a computer software program was developed for CDOT by Dr. Rajapopal Arudi. This program should be used when determining the user cost in a work zone. Work zone cost should then be included in the construction or rehabilitation section in the LCCA module of the DARWin® program.

EXAMPLE:

Compare 9.0" HBP alternative to a 12" PCCP alternative on a 4-lane section of I-70 (2-lanes per direction) near Bethune Colorado from MP 417 to MP 427. It is estimated that the HBP alternative will take 54 construction days working from 8:00 a.m. to 5:00 p.m. of a single lane closure per direction. The 12" PCCP alternative will take 100 construction days per direction using a cross over. Each of the HBP rehabilitation cycles will take approximately 20 construction days and the PCCP rehabilitation will take approximately 30 construction days each working from 8:00 a.m. to 5:00 p.m. Detailed information on this example can be found in Appendix D for the HBP information and Appendix E for the PCCP.

HBP Cash flow diagram:



Initial Construction = 110,600 tons of HBP @ $45.00/ton =		$4,976,995
	10% for Preliminary Engineering	497,699
	12% for Const. Engineering	597,239
	15% for Traffic Control	788,024
	Workzone User Cost	356,268
	Total =	$ 7,216,225

Annual Maintenance cost = $1,600 per year per lane mile

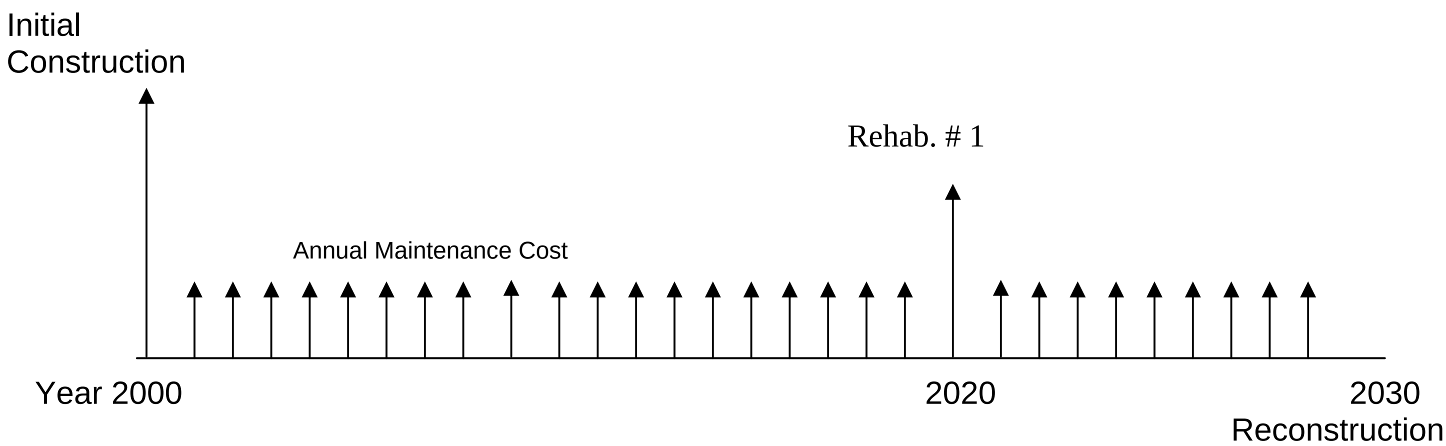
Rehabilitation #1 = Rehabilitation # 2 = Rehabilitation # 3 =

2.0” HBP overlay full width = 24,578 tons @ $52.00/ton =		$1,278,043
	10% for Preliminary Engineering	127,804
	12% for Const. Engineering	153,365
	15% for Traffic Control	191,706
	Workzone User Cost	131,502
	Total =	$ 1,882,420

Net Present Value of the HBP alternative = $7,216,225 (Const.) + $490,028 (annual maint. cost) +
rehab. # 1 = $1,882,420 (0.730689) = $1,375,463 +
rehab. # 2 = $1,882,420 (0.533908) = $1,005,039 +
rehab. # 3 = $1,882,420 (0.405726) = $ 763,747

Net Present Value of the HBP alternative per direction = $10,850,502

PCCP Cash flow diagram:



Initial Construction = 222,933 Sq. Yds. of PCCP @ $30.00/sq.yd. = $6,688,000

10% for Preliminary Engineering	668,800
12% for Const. Engineering	802,560
15% for Traffic Control	1,003,200
Workzone User Cost	501,183
	Total = $9,663,743

Annual Maintenance cost = $50.00 per year per lane mile

Rehabilitation #1 = 1% slab replacement and 0.25" diamond grinding in the travel lanes

1408 sq. yd. of 12" slab replacement @ $ 6.50/sq.yd.-inch	= $109,824
140,800 sq.yds diamond grinding @ $5.00/sq.yd.	704,000
10% for Preliminary Engineering	81,382
12% for Const. Engineering	97,659
15% for Traffic Control	122,074
Workzone User Cost	196,549
	Total = $1,311,488

Net Present Value of the PCCP alternative = $9,663,743 (Const.) + $16,527 (annual maint. cost) +
rehab. # 1 = $1,311,488 (0.456387) = $598,546

Net Present Value of the PCCP alternative per direction = $10,278,816

Comparing the two alternatives = $\frac{\$10,850,502 - \$10,278,816}{\$10,850,502}$ = 5.3%

Since the two alternatives are within 10% of each other, they may be considered to have equivalent designs.

Other secondary factors can and should be used to help in the pavement selection.

SUMMARY

CDOT takes the view that engineers engaged in their profession should use what is termed “good practice” when designing projects. Thus, the purpose of this report is to provide the outline for this “good practice” in this specific engineering feat, which is determining the life-cycle cost analysis. We hope that the guidance, recommendations, and default values provided here will help the engineer in conducting a LCCA in pavement design. The engineer in selecting pavement type and rehabilitation strategies should use locally available or site specific information when performing a LCCA.

Reference:

(1) Report No. Dot-FAA-RD-81-78, Federal Aviation Administration, Department of Transportation, Washington, D.C. (1981) by J.A. Epps and C.V. Wootan

(2) Report No. FHWA/OH-97/008, Federal Highway Administration, Department of Transportation, Washington, D.C. (1997) by R. Arudi, I. Minkarah, and P. Pant

Region One Concrete Pavements
Annual maintenance cost per lane mile

Fiscal Year	SH 40 Const. 1995 MP 386 to 398	I-70 Const. 1989 MP 288 to 290	I-70 Const. 1960 MP 293 to 318	I-70 Const. 1991 MP 322 to 342	I-70 Const. 1968 MP 348 to 358
87/88	n/a	n/a	0	n/a	0
88/89	n/a	n/a	0	n/a	0
89/90	n/a	0	0	n/a	0
90/91	n/a	0	1	0	14
91/92	n/a	0	2	2	105
92/93	n/a	0	0	0	0
93/94	n/a	0	0	0	0
94/95	n/a	42	34	12	473
95/96	0	80	301	17	0
96/97	0	1005	118	1001	0
Average	0	141	46	147	59

Fiscal Year	I-70 Const. 1993 MP 395 to 418	I-70 Const. 1994 MP 439 to 449.5	SH 83 Const. 1990 MP 53.5 to 61	SH 285 Const. 1993 MP 244.5 to 246
87/88	n/a	n/a	n/a	n/a
88/89	n/a	n/a	n/a	n/a
89/90	n/a	n/a	n/a	n/a
90/91	n/a	n/a	n/a	n/a
91/92	n/a	n/a	156	n/a
92/93	n/a	n/a	17	n/a
93/94	0	n/a	13	n/a
94/95	0	0	0	27
95/96	0	2	0	0
96/97	599	0	30	0
Average	150	1	36	9

Average = $65 / year / lane mile

Project Standard Deviation = $60 / year / lane mile

Year-to-year standard deviation = $216

Region Two Concrete Pavements
Annual maintenance cost per lane mile

Fiscal Year	SH 115 Const. 1993 MP 14 - 18
87/88	n/a
88/89	n/a
89/90	n/a
90/91	n/a
91/92	n/a
92/93	n/a
93/94	0
94/95	0
95/96	51
96/97	0
Average	13

Average = $13 / year / lane mile

Project Standard Deviation = N/A

Year-to-year standard deviation = $26

Region Three Concrete Pavements
Annual maintenance cost per lane mile

Fiscal Year	I - 70 Const. pre 1987 MP 86.5 - 97.0
87/88	664
88/89	0
89/90	19
90/91	0
91/92	0
92/93	0
93/94	4
94/95	55
95/96	23
96/97	192
Average	96

Average = $96 / year / lane mile

Project Standard Deviation = N/A

Year-to-year standard deviation = $208

Region Four Concrete Pavements
Annual maintenance cost per lane mile

Fiscal Year	I - 25 Const. 1985 MP 243 to 282	SH 34 Const. 1991 MP 106.5 to 109	SH 34 Const. 1991 MP 114 to 121	I - 76 Const. pre 87 MP 25 to 125.5	I - 76 Const. pre 87 MP 128 to 184	SH 85 Const. 1993 MP 261 to 277
87/88	38	n/a	n/a	45	0	n/a
88/89	9	n/a	n/a	3	0	n/a
89/90	125	n/a	n/a	193	55	n/a
90/91	110	n/a	n/a	2	1	n/a
91/92	102	n/a	n/a	495	0	n/a
92/93	381	0	0	226	86	n/a
93/94	8	0	0	121	78	n/a
94/95	6	351	0	175	0	23
95/96	88	0	0	185	11	7
96/97	119	1367	0	43	489	17
Average	99	344	0	368	72	16

Fiscal Year	SH 85 Const. 1990 MP 0.0 to 2	SH 119 Const. pre 87 MP 54.5 to 56	SH 138 Const. 1990 MP 0.0 to 2.5	SH 157 Const. pre 87 MP 3 to 5	SH 287 Const. 1990 MP 309 to 314	SH 287 Const. 1991 MP 350 to 354
87/88	n/a	0	n/a	0	n/a	n/a
88/89	n/a	0	n/a	0	n/a	n/a
89/90	n/a	150	n/a	817	n/a	n/a
90/91	n/a	188	0	0	n/a	n/a
91/92	0	88	79	0	12	n/a
92/93	0	51	1008	452	68	4
93/94	0	742	0	0	317	17
94/95	0	637	0	0	48	889
95/96	67	358	0	1843	766	79
96/97	0	1691	0	1867	90	5
Average	11	391	155	498	217	199

Average = $179 / year / lane mile

Project Standard Deviation = $160 / year / lane mile

Year-to-year standard deviation = $400 / year / lane mile

Region Five Concrete Pavements
Annual maintenance cost per lane mile

Fiscal Year	SH 160 Const. 1993 MP 38 to 39.5	SH 160 Const. 1995 MP 183 to 186.5	SH 550 Const. 1991 MP 21 to 24
87/88	n/a	n/a	n/a
88/89	n/a	n/a	n/a
89/90	n/a	n/a	n/a
90/91	n/a	n/a	n/a
91/92	n/a	n/a	0
92/93	n/a	n/a	0
93/94	6	n/a	175
94/95	74	n/a	773
95/96	31	36	58
96/97	29	2	392
Average	35	19	233

Average = $96 / year / lane mile

Project Standard Deviation = $119 / year / lane mile

Year-to-year standard deviation = $231 / year / lane mile

Region Six Concrete Pavements
Annual maintenance cost per lane mile

Fiscal Year	I – 25 Const. pre 87 MP 213.5-216.5	I-70 Const. 1968 MP 259 to 270	I-70 Const. 1964 MP 273 to 274.5	I-70 Const. 1964 MP 280.5-285.5
87/88	0	0	0	0
88/89	23	26	12	104
89/90	254	0	0	0
90/91	273	56	0	0
91/92	165	0	0	0
92/93	79	0	0	0
93/94	23	960	0	0
94/95	13	0	0	776
95/96	65	0	0	9
96/97	33	0	0	0
Average	93	104	1	89

Fiscal Year	I-76 Const. 1976 MP 5.5 to 12	SH 85 Const. 1987 MP 205 to 209.5	I - 225 Const. 1968 MP 4 - 12
87/88	0	0	0
88/89	0	497	0
89/90	74	0	0
90/91	64	0	1471
91/92	413	0	0
92/93	0	0	2161
93/94	0	40	1954
94/95	0	0	0
95/96	1108	0	0
96/97	0	0	0
Average	166	54	559

Average = $152 / year / lane mile

Project Standard Deviation = $186 / year / lane mile

Year-to-year standard deviation = $402 / year / lane mile

Region One HBP Pavement
Annual maintenance cost per lane mile

Fiscal Year	SH 6 Const. Oct. 86 MP 210 - 212	SH 40 Const. April 86 MP 430 - 433	SH 40 Const. April 86 MP 440 - 445	SH 71 Const. 1986 MP 92 - 97
87/88	54	114	693	6
88/89	449	2339	1721	92
89/90	191	66	1389	0
90/91	5751	5511	4086	442
91/92	3472	111	1206	0
92/93	223	2160	188	729
93/94	7456	5541	5290	1884
94/95	207	5724	4425	26
95/96	4638	13	865	0
96/97	385	5531	7841	0
Average	2283	2711	2770	318

Fiscal Year	SH 59 Const. Nov. 78 MP 9.5 - 15.0	SH 59 Const. Nov. 91 MP 15 -17	SH 59 Const. Nov. 91 MP 29.5 - 33.5	SH 86 Const. Sept. 81 MP 12 - 14	
87/88	80	n/a	n/a	176	
88/89	1304	n/a	n/a	223	
89/90	110	n/a	n/a	192	
90/91	575	n/a	n/a	766	
91/92	2302	No Data	7	335	
92/93	3787	338	115	1940	
93/94	944	2265	1268	5050	
94/95	No Data	No Data	76	No Data	
95/96	0	0	627	30042*	* Excluded
96/97	47	No Data	388	9614	
Average	1017	868	414	2287	

Average = $1584/ year / lane mile

Standard Deviation = $1033 / year / lane mile

Year-to-year standard deviation = $2330

Region Two HBP Pavement
Annual maintenance cost per lane mile

Fiscal Year	I-25 Const. Aug. 83 MP 1.5 - 7.0	I-25 Const. Nov. 85 MP 41.2 - 48.8	I-25 Const. Aug. 85 MP 60.7 - 65.3	I-25 Const. July 71 MP 111.4 – 116
87/88	No Data	No Data	No Data	No Data
88/89	124	61	55	440
89/90	450	94	156	568
90/91	335	38	82	2135
91/92	666	71	1676	174
92/93	420	488	3635	106
93/94	421	722	2982	73
94/95	25	36	3	182
95/96	222	46	0	285
96/97	27	191	4	3216
Average	299	194	955	798

Fiscal Year	SH 67 Const. April 78 MP 12.0 - 12.6	SH 69 Const. May 79 MP 41.0 - 47.1	SH 96 Const. May 78 MP 17.8 - 24.1
87/88	195	No Data	No Data
88/89	0	9	8
89/90	85	18	4
90/91	12	35	46
91/92	205	111	73
92/93	445	1125	86
93/94	2346	4504	234
94/95	6470	65	3
95/96	12	2288	8
96/97	2153	5	0
Average	1192	907	51

Average = $628 / year / lane mile

Standard Deviation = $440 / year / lane mile

Year-to-year standard deviation = $1231

Region Three HBP Pavement
Annual maintenance cost per lane mile

Fiscal Year	SH 50 Const. Oct. 92 MP 64.3 - 67.5	I-70 Const. Nov. 80 MP 58.3 - 60.5	I-70 Const. June 83 MP 73.8 - 81.8	I-70 Const. Jan. 81 MP 131 - 137.5	SH 133 Const. Sept. 83 MP 15.4 - 16.9
87/88	n/a	37	262	352	3089
88/89	n/a	No Data	No Data	No Data	No Data
89/90	n/a	95	71	454	150
90/91	n/a	67	161	511	55
91/92	23	29	1205	1467	1822
92/93	0	48	328	492	30
93/94	0	1053	3495	8687	1556
94/95	No Data	6169	2266	631	37
95/96	No Data	329	1097	1047	1485
96/97	257	947	239	140	1288
Average	70	975	1014	1531	1057

Average = $929/ year / lane mile

Standard Deviation = $531 / year / lane mile

Year-to-year standard deviation = $1730

Region Four HBP Pavement
Annual maintenance cost per lane mile

Fiscal Year	SH 14 Const. Sept. 79 MP 63 – 65	SH 14 Const. Oct. 92 MP 218.1 - 221.9	US 34 Const. May 80 MP 78 - 80	US 34 Const. Feb. 79 MP 113 - 114
87/88	2581	n/a	2380	68
88/89	5339	n/a	2115	562
89/90	No Data	n/a	No Data	No Data
90/91	No Data	n/a	1930	5
91/92	No Data	n/a	3445	1688
92/93	2128	n/a	117	27
93/94	1964	0	3461	48
94/95	2857	0	20	300
95/96	123	240	12	626
96/97	643	9072	4	435
Average	2234	2328	1498	418

Fiscal Year	SH 55 Const. Oct. 87 MP 0.7 - 1.7	US 287 Const. Oct 87 MP 307.9 - 309.1	SH 157 Const. May 80 MP 1 - 2.1	SH 157 Const. July 83 MP 2.1 - 2.6
87/88	295	n/a	1470	2466
88/89	164	1957	192	No Data
89/90	No Data	No Data	No Data	No Data
90/91	0	No Data	0	0
91/92	351	No Data	0	0
92/93	309	8	0	0
93/94	70	1224	0	0
94/95	17	564	0	0
95/96	0	12	0	0
96/97	871	1206	0	0
Average	231	829	185	308

Average = $1004 / year / lane mile

Standard Deviation = $897/ year / lane mile

Year-to-year standard deviation = $1559

Region Five HBP Pavement
Annual maintenance cost per lane mile

Fiscal Year	SH62 Const. 1989 MP 19.0 - 22.8	SH 145 Const. 1984 MP 4.0 - 8.0	US 160 Const. 1984 MP 84.0 - 87.0	US 550 Const. 1980 MP 37.0 - 40.0	
87/88	n/a	No Data	No Data	No Data	
88/89	No Data	No Data	No Data	No Data	
89/90	559	7	4096	No Data	
90/91	440	27	3827	1034	
91/92	594	471	10608	3274	
92/93	5544	3401	6878	1479	
93/94	2175	384	8279	657	
94/95	554	98	3666	2205	
95/96	2010	406	8062	780	
96/97	876	107	10151	18525*	* Excluded
Average	1594	613	6946	1572	

Average = $ 2681 / year /lane mile

Standard Deviation = $ 2880/year/lane mile

Year-to-year standard deviation = $3146

Region Six HBP Pavement

Annual maintenance cost per lane mile

Fiscal Year	SH 72 Const. June 72 MP 0.1 - 2.3	I-76 Const. May 86 MP 0.7 - 1.5	I-76 Const. Dec. 87 MP 1.5 - 3.1	I-76 Const. Nov. 89 MP 3.1 - 4.2
87/88	No Data	No Data	No Data	n/a
88/89	2575	8758	4392	n/a
89/90	3	1543	325	0
90/91	32	3926	2390	865
91/92	291	2638	1979	1337
92/93	6652	1630	1653	134
93/94	490	837	410	No Data
94/95	567	1494	521	235
95/96	4825	359	599	50
96/97	3974	7048	3515	2567
Average	2157	3137	1754	741

Fiscal Year	SH 88 Const. Nov. 76 MP 17.7 - 18.9	470 Const. Oct. 90 MP 5.5 - 6.4	470 Const. July 91 MP 6.4 - 10.2
87/88	No Data	n/a	n/a
88/89	188	n/a	n/a
89/90	258	54	n/a
90/91	204	777	11
91/92	3112	536	163
92/93	1458	308	64
93/94	No Data	952	1978
94/95	No Data	1352	1283
95/96	58	1508	316
96/97	6	867	795
Average	755	794	659

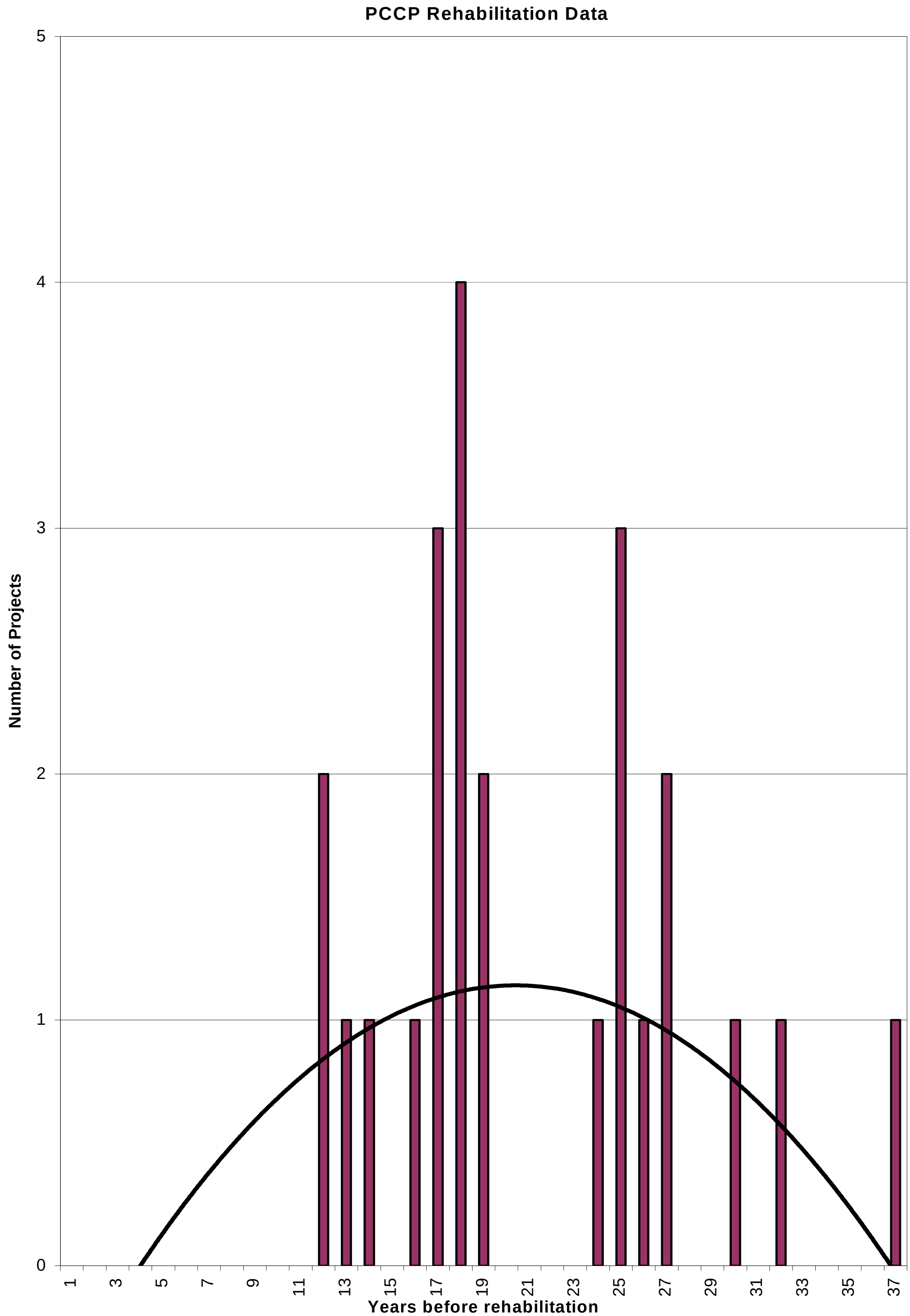
Average = $1428 / year / lane mile

Standard Deviation = $955 / year / lane mile

Year-to-year standard deviation = $1897

PCCP Rehabilitation Data

Highway	Milepost From - To	Date Constructed	Date of 1st Rehab.	Years Before Rehab.	Type of Rehab.	Date of Reconstruction	Yrs. Before Reconstruction
I - 25	5 - 9	1950	1966	16	2" HBP		
	26 - 36	1958	1982	24	4" HBP (SB only)		
	36 - 41	1958	1984	26	4" HBP		
	160 - 163	1949	1962	13	2" HBP		
	163 - 167	1967	1984	17	2" HBP		
	167 - 172	1967	1984	17	2" HBP		
	172 - 182	1966	1984	18	2" HBP		
	182 - 193	1958	1972	14	2" HBP		
	192 - 193	1958	1976	18	1.5" HBP		
	193 - 196	1958	1976	18	2" HBP		
	196 - 198	1958	1976	18	1.5" HBP		
	198 - 202	1958	1975	17	1.5" HBP		
	202 - 204	1949	1968	19	2" HBP		
	209 - 210	1956	1968	12	1.5" HBP		
	254 - 260	1962				1986	24
	260 - 264	1964				1987	23
	264 - 268	1967				1988	21
	268 - 274	1967				1989	22
	274 - 282	1967				1990	23
	282 - 299	1963				1998	35
SH 34	114 - 121	1954				1992	38
SH 36	52 - 54	1968	1980	12	1.25" HBP		
I - 70	86 - 97	1967				1999	32
	259 - 262	1969	1996	27	4" HBP		
	262 - 265	1967	1997	30	4" HBP		
	265 - 270	1966				1999	33
	270 - 273	1965	1990	25	3.75" HBP		
	273 - 275	1962				1999	37
	275 - 280	1963				1985	22
	280 - 286	1964				1998	34
	293 - 306	1962				1998	36
	306 - 312	1963	1982	19	2" HBP	1997	34
	312 - 318	1963				1997	34
	318 - 322	1964	1989	25	Grind & 1" PMSC		
	322 - 329	1965				1991	26
	329 - 338	1967				1995	28
	338 - 342	1968	1995	27	2" HBP		
	348 - 358	1968				1996	28
	402 - 418	1970				1993	23
	418 - 427	1970	1995	25	2" HBP		
I - 76	6 - 12	1976				1999	23
	12 - 16	1961	1993	32	7.5" HBP		
	21 - 23	1956				1986	30
	23 - 27	1956				1981	25
	27 - 31	1956				1982	26
	31 - 50	1961				1998	37
	50 - 62	1961				1991	30
	62 - 74	1961				1994	33
	74 - 90	1961	1998	37	2" HBP		
	124 - 128	1961				1995	34
	128 - 140	1961				1992	31
	140 - 149	1961				1991	30
SH 85	261 - 267	1957				1993	36
I – 225	4 - 12	1968				1999	31
			Average =	21.1		Average =	29.6
			Standard Dev.=	6.6		Standard Dev. =	5.3

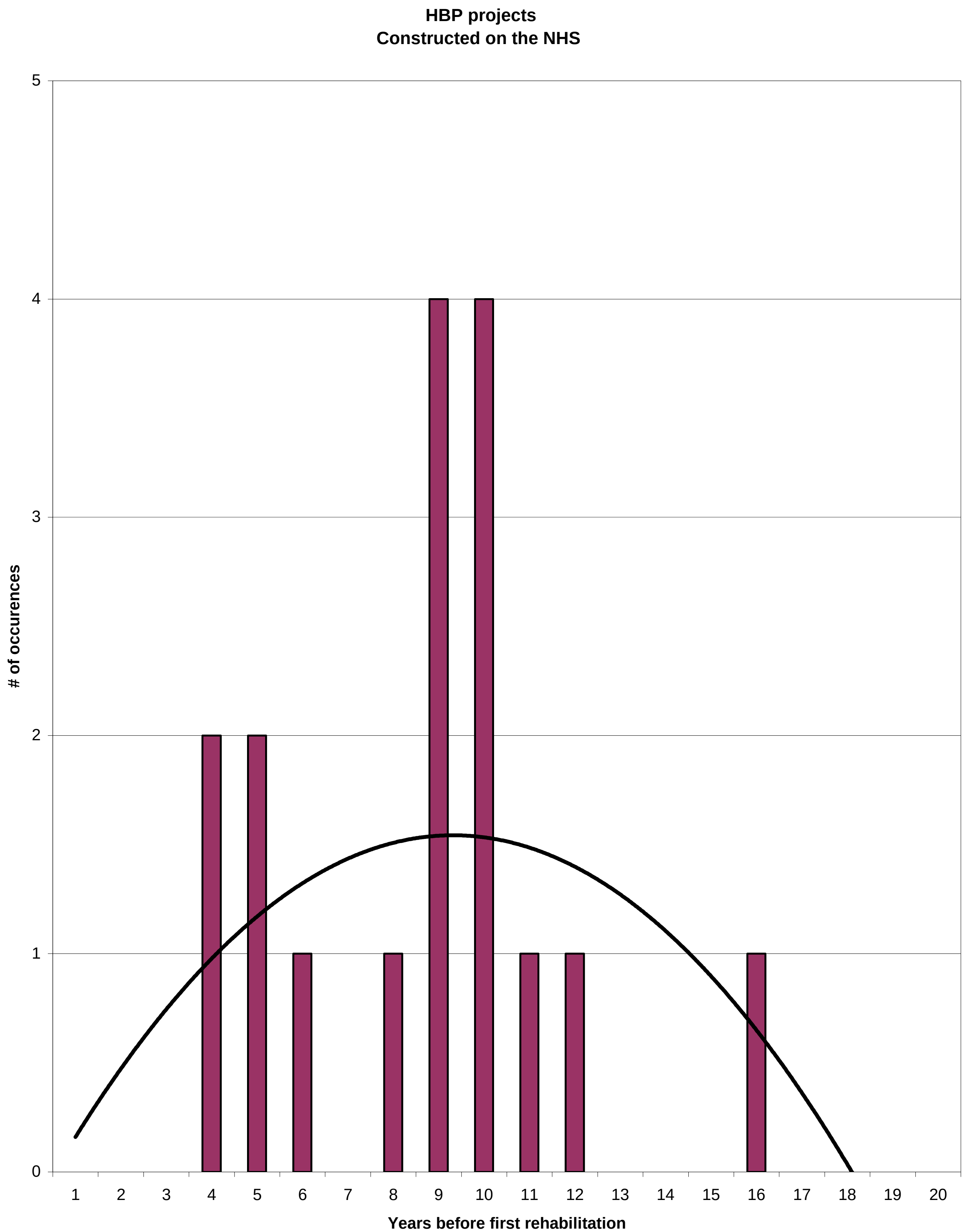


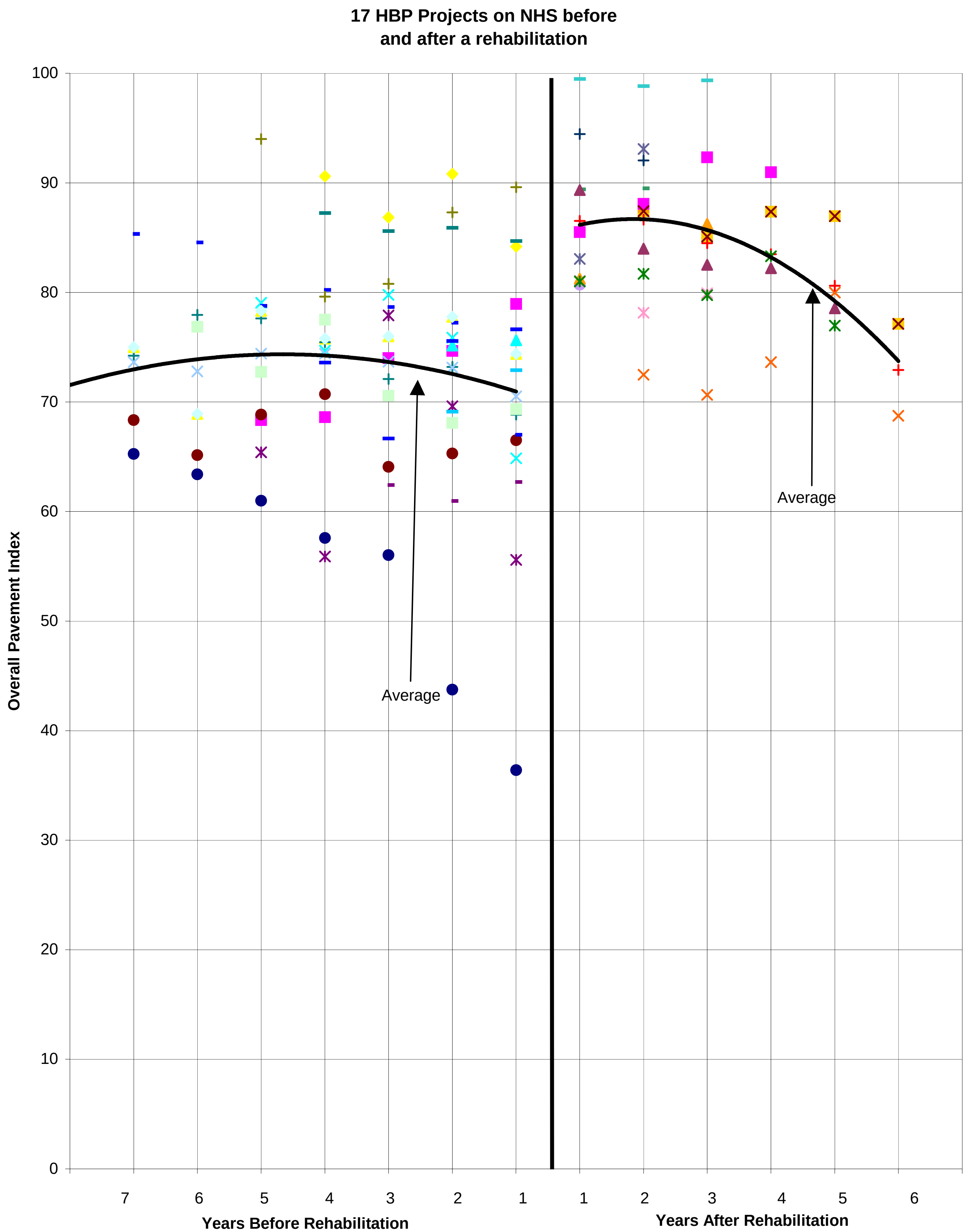
PCCP Rehabilitation Data
Number of Projects
Years before rehabilitation
0
1
2
3
4
5
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37

HBP Rehabilitation Data
For 17 projects constructed on the NHS

Highway	Milepost From - To	Date Constructed	Date of 1st Rehab.	Years Before Rehab.	Type of Rehab.
I - 25	1.5 - 7	1983	1993	10	2" HBP
	41.2 - 48.8	1985	1997	12	2" HBP
	60.7 - 65.3	1985	1994	9	2" HBP
US 34	78 - 80	1980	1996	16	2" HBP
SH 40	430 - 432.7	1986	1995	9	1" HBP
	440 - 445	1986	1995	9	1" HBP
SH 50	64.3 - 67.5	1992	1997	5	1" HBP
I - 70	58.3 - 60.5	1980	1989	9	1.25" HBP & 0.75" PMSC
	73.8 - 81.8	1983	1989	6	1" HBP
	131 - 137.5	1981	1985	4	0.75" PMSC
I - 76	0.7 - 1.5	1986	1997	11	1" HBP
	1.5 - 3.1	1987	1997	10	1" HBP
	3.1 - 4.2	1989	1997	8	1" HBP
SH 88	17.7 - 18.9	1976	1986	10	1.25" HBP
SH 157	1.0 - 2.1	1980	1985	5	1.5" HBP
	2.1 - 2.6	1983	1987	4	1.5" HBP
SH 287	308 - 309.1	1987	1997	10	1" HBP

Average = 8.6
Standard Deviation = 3.1

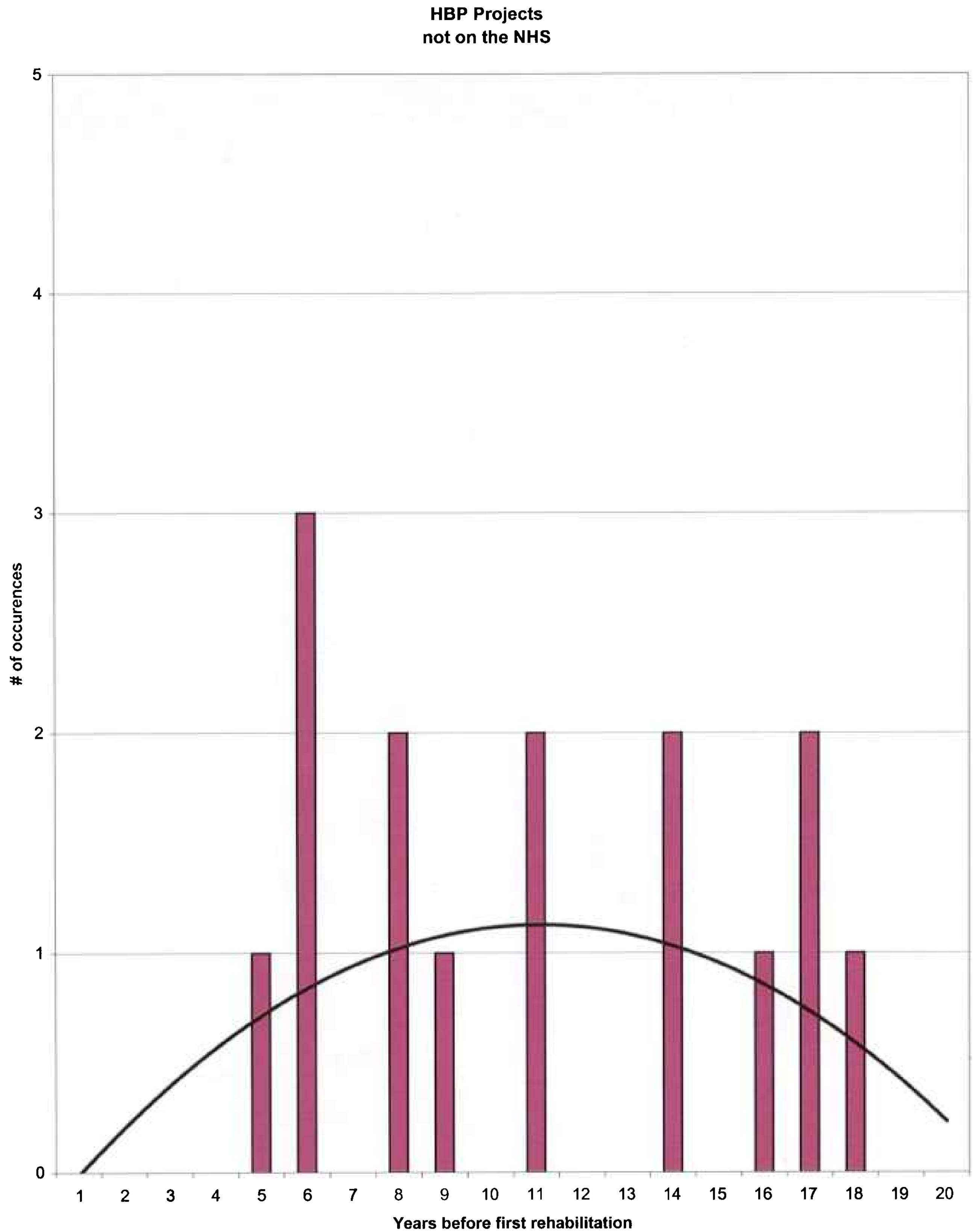

HBP projects
Constructed on the NHS
# of occurences
Years before first rehabilitation
0
1
2
3
4
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

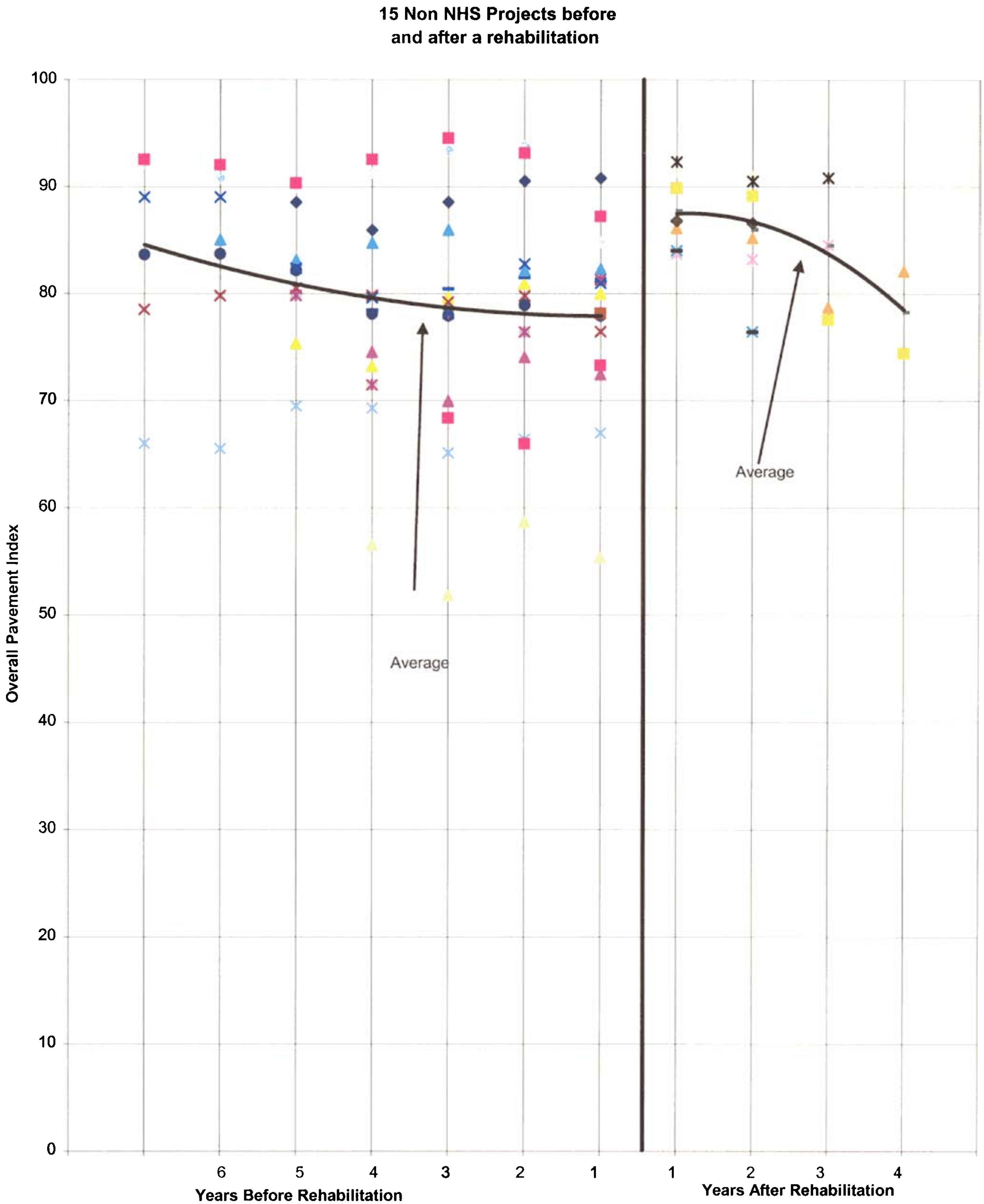

17 HBP Projects on NHS before
and after a rehabilitation
Overall Pavement Index
100
90
80
70
60
50
40
30
20
10
0
7
6
5
4
3
2
1
1
2
3
4
5
6
Years Before Rehabilitation
Years After Rehabilitation
Average
Average

HBP Rehabilitation Data
For 15 projects not on the NHS

Highway	Milepost From - To	Date Constructed	Date of 1st Rehab.	Years Before Rehab.	Type of Rehab.
SH 6	210 - 212	1986	1995	9	1.5" HBP
SH 14	63 - 65	1979	1983	14	2" HBP
	218 - 222	1992	1997	5	1.5" HBP
SH 55	0.7 - 1.7	1987	1995	8	1.5" HBP
SH 59	15 - 17	1991	1997	6	1" HBP
	29.5 - 33.5	1991	1997	6	1" HBP
SH 62	19 - 22.8	1989	1995	6	1" HBP
SH 67	12 - 12.6	1978	1995	17	2" HBP
SH 69	41 - 47.1	1979	1997	18	1" HBP
SH 71	92 - 97	1986	1997	11	1" HBP
SH 86	12 - 14	1981	1995	14	1" HBP
SH 96	17.8 - 24.1	1978	1995	17	1.5" HBP
SH 133	15.4 -16.9	1983	1991	8	1.5" HBP
SH 160	84 - 87	1984	1995	11	1" HBP
SH 550	37 - 40	1980	1996	16	1" HBP

Average = 11.1
Standard Deviation = 4.6


HBP Projects
not on the NHS
# of occurences
Years before first rehabilitation
0
1
2
3
4
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20


15 Non NHS Projects before
and after a rehabilitation
Overall Pavement Index
100
90
80
70
60
50
40
30
20
10
0
6
5
4
3
2
1
Years Before Rehabilitation
1
2
3
4
Years After Rehabilitation
Average
Average

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare Computer Software Product

Life Cycle Cost Module

HBP Alternative

Life Cycle Cost Data

Summary

Analysis Period	30 years
Project Length	10 mi
Discount Rate	4 %
Number of Lanes in One Direction	2
Type of Roadway	Divided

Total Costs -- Using NPV on a basis of total costs for one direction

Initial Construction Cost	$7,408,290
Rehabilitation Cost	$3,442,215
Salvage Value	
Total Cost	$10,850,506

Initial Construction

9.0" HBP

Construction Year
Performance Period

Cost Information -- Using NPV on a basis of total costs for one direction

Information Type	Source	Costs at Year of Construction (One Direction)	Net Costs
Construction	DARWin Calculated	$7,216,224.54	$7,216,224.54
Maintenance	DARWin Calculated	$192,065.75	$192,065.75
Total	-	$7,408,290.29	$7,408,290.29

Rehabilitation #1

2" HBP Overlay

Rehabilitation Year
Performance Period

Cost Information -- Using NPV on a basis of total costs for one direction

Information Type	Source	Costs at Year of Rehabilitation (One Direction)	Net Costs
Construction	DARWin Calculated	$1,882,420.04	$1,375,465.88
Maintenance	DARWin Calculated	$192,065.75	$140,340.56
Total	-	$2,074,485.79	$1,515,806.45

Rehabilitation #2

2" HBP Overlay

Rehabilitation Year	2016
Performance Period	7 years

Cost Information -- Using NPV on a basis of total costs for one direction

Information Type	Source	Costs at Year of Rehabilitation (One Direction)	Net Costs
Construction	DARWin Calculated	$1,882,420.04	$1,005,039.45
Maintenance	DARWin Calculated	$167,748.38	$89,562.23
Total	-	$2,050,168.42	$1,094,601.68

Rehabilitation #3

2" HBP Overlay

Rehabilitation Year	2023
Performance Period	7 years

Cost Information -- Using NPV on a basis of total costs for one direction

Information Type	Source	Costs at Year of Rehabilitation (One Direction)	Net Costs
Construction	DARWin Calculated	$1,882,420.04	$763,747.38
Maintenance	DARWin Calculated	$167,748.38	$68,059.93
Total	-	$2,050,168.42	$831,807.32

Salvage Values

Salvage Year	2030

Cost Information -- Using NPV on a basis of total costs for one direction

Phase	Description	Source	Salvage Value	Net Value
Initial Construction	-	DARWin Calculated	$0.00	$0.00
Rehabilitation #1	-	DARWin Calculated	$0.00	$0.00
Rehabilitation #2	-	DARWin Calculated	$0.00	$0.00
Rehabilitation #3	-	DARWin Calculated	$0.00	$0.00

Initial Construction Maintenance Costs

Year Maintenance Costs Begin	2001
Annual Maintenance Costs	$1,600.00 per lane mi
Annual Increase in Maintenance Costs	0 %

Rehabilitation #1 Maintenance Costs

Year Maintenance Costs Begin	2009
Annual Maintenance Costs	$1,600.00 per lane mi
Annual Increase in Maintenance Costs	0 %
Calculated Non Discounted Maintenance Costs (One Direction)	$192,065.75

Rehabilitation #2 Maintenance Costs

Year Maintenance Costs Begin	2017
Annual Maintenance Costs	$1,600.00 per lane mi
Annual Increase in Maintenance Costs	0 %
Calculated Non Discounted Maintenance Costs (One Direction)	$167,748.38

Rehabilitation #3 Maintenance Costs

Year Maintenance Costs Begin	2024
Annual Maintenance Costs	$1,600.00 per lane mi
Annual Increase in Maintenance Costs	0 %
Calculated Non Discounted Maintenance Costs (One Direction)	$167,748.38

Initial Construction Pay Items

Name	Lane	Layer	Unit	Unit Cost	Quantity	Total Cost
HBP Grading SG(96) PG 64-28	T.L.		ton	$45.00	110,600	$4,976,994.54
Workzone User Cost	T.L.		lump sum	$356,268.00	1	$356,268.00
15% for Traffic Control	T.L.		lump sum	$788,024.00	1	$788,024.00
10% for preliminary engineering	T.L.		lump sum	$497,699.00	1	$497,699.00
12% for const. engineering	T.L.		lump sum	$597,239.00	1	$597,239.00

Non Discounted Costs (One Direction)

Traffic Lane	$7,216,224.54
Inner Shoulder	$0.00
Outer Shoulder	$0.00
Miscellaneous	$0.00
Total Non Discounted Cost (One Direction)	$7,216,224.54

Rehabilitation #1 Pay Items

Name	Lane	Layer	Unit	Unit Cost	Quantity	Total Cost
HBP Grading SG(96) PG 64-28	T.L.	1	ton	$52.00	24,578	$1,278,043.04
Workzone User Cost	T.L.	1	lump sum	$131,502.00	1	$131,502.00
15% for Traffic Control	T.L.	1	lump sum	$191,706.00	1	$191,706.00
10% for preliminary engineering	T.L.	1	lump sum	$127,804.00	1	$127,804.00
12% for const. engineering	T.L.	1	lump sum	$153,365.00	1	$153,365.00

Non Discounted Costs (One Direction)

Traffic Lane	$1,882,420.04
Inner Shoulder	$0.00
Outer Shoulder	$0.00
Miscellaneous	$0.00
Total Non Discounted Cost (One Direction)	$1,882,420.04

Rehabilitation #2 Pay Items

Name	Lane	Layer	Unit	Unit Cost	Quantity	Total Cost
HBP Grading SG(96) PG 64-28	T.L.		ton	$52.00	24,578	$1,278,043.04
Workzone User Cost	T.L.		lump sum	$131,502.00	1	$131,502.00
15% for Traffic Control	T.L.		lump sum	$191,706.00		$191,706.00
10% for preliminary engineering	T.L.		lump sum	$127,804.00	1	$127,804.00
12% for const. engineering	T.L.		lump sum	$153,365.00		$153,365.00

Non Discounted Costs (One Direction)

Traffic Lane	$1,882,420.04
Inner Shoulder	$0.00
Outer Shoulder	$0.00
Miscellaneous	$0.00
Total Non Discounted Cost (One Direction)	$1,882,420.04

Rehabilitation #3 Pay Items

Name	Lane	Layer	Unit	Unit Cost	Quantity	Total Cost
HBP Grading SG(96) PG 64-28	T.L.		ton	$52.00	24,578	$1,278,043.04
Workzone User Cost	T.L.		lump sum	$131,502.00		$131,502.00
15% for Traffic Control	T.L.		lump sum	$191,706.00		$191,706.00
10% for preliminary engineering	T.L.		lump sum	$127,804.00		$127,804.00
12% for const. engineering	T.L.		lump sum	$153,365.00		$153,365.00

Non Discounted Costs (One Direction)

Traffic Lane	$1,882,420.04
Inner Shoulder	$0.00
Outer Shoulder	$0.00
Miscellaneous	$0.00
Total Non Discounted Cost (One Direction)	$1,882,420.04

Initial Construction -- Traffic Lane Dimensions

Layer	Material Description	Width (ft)	Thickness (in)
1	HBP	38	9

Initial Construction -- Inner Shoulder Dimensions

Layer	Material Description	Width (ft)	Inner Thickness (in)	Outer Thickness (in)

Initial Construction -- Outer Shoulder Dimensions

	INPUT DATA	
Project Name	Bethune	
Freeway Name	I-70	
Input Filename	C:\CDOT\BETHUNE3.WZM	
Project Start Date		
Project End Date		
Design Speed	75 mph	
Speed Limit	75 mph	
Workzone Speed Limit	45 mph	
Grade	2.0 %	
Work Zone Length	10.00 miles	
Total Number of Lanes	2	
Number of Open Lanes	1	
Number of Temporary Lanes	0	
AADT, Directional	3925	
Percentage of Single Unit Trucks	8.3 %	
Percentage of Combination Trucks	30.2 %	
Functional Class	Rural Interstate (Weekday)	
	OUTPUT SUMMARY	
TYPE OF WORK	**ADDITIONAL USER COST**	**DURATION**
	DUE TO WORKZONE	
403-HBP (Asphalt) <= 3.0 inch	$356,267.98	54
TOTAL ADDL. USER COST	$356,267.98	54
TOTAL USER COST FOR NORMAL CONDITION (WITH NO WORKZONE)		
FOR A DURATION OF 54 DAYS = $1,146,663.91		
Disclaimer:		
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	INPUT DATA	
Project Name	Bethune	
Freeway Name	I-70	
Input Filename	C:\CDOT\BETHUNE4.WZM	
Project Start Date		
Project End Date		
Design Speed	75 mph	
Speed Limit	75 mph	
Workzone Speed Limit	45 mph	
Grade	2.0 %	
Work Zone Length	10.00 miles	
Total Number of Lanes	2	
Number of Open Lanes	1	
Number of Temporary Lanes	0	
AADT, Directional	3925	
Percentage of Single Unit Trucks	8.3 %	
Percentage of Combination Trucks	30.2 %	
Functional Class	Rural Interstate (Weekday)	
	OUTPUT SUMMARY	
TYPE OF WORK	**ADDITIONAL USER COST DUE TO WORKZONE**	**DURATION**
403-HBP (Patching)	$19,725.23	3
403-HBP (Asphalt) <= 2.0 inch	$111,776.30	17
TOTAL ADDL. USER COST	$131,501.52	20
TOTAL USER COST FOR NORMAL CONDITION (WITH NO WORKZONE)		
FOR A DURATION OF 20 DAYS = $423,243.35		
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1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Life Cycle Cost Module

PCCP Alternative

Life Cycle Cost Data

Summary

Analysis Period	30 years
Project Length	10 mi
Discount Rate	4 %
Number of Lanes in One Direction	2
Type of Roadway	Divided

Total Costs -- Using NPV on a basis of total costs for one direction

Initial Construction Cost	$9,676,877
Rehabilitation Cost	$601,939
Salvage Value	
Total Cost	$10,278,816

Initial Construction

12" PCCP

Construction Year	2000
Performance Period	20 years

Cost Information -- Using NPV on a basis of total costs for one direction

Information Type	Source	Costs at Year of Construction (One Direction)	Net Costs
Construction	DARWin Calculated	$9,663,743.00	$9,663,743.00
Maintenance	DARWin Calculated	$13,133.94	$13,133.94
Total	-	$9,676,876.94	$9,676,876.94

Rehabilitation #1

Diamond Grinding

Rehabilitation Year	2020
Performance Period	10 years

Cost Information -- Using NPV on a basis of total costs for one direction

Information Type	Source	Costs at Year of Rehabilitation (One Direction)	Net Costs
Construction	DARWin Calculated	$1,311,488.00	$598,546.00
Maintenance	DARWin Calculated	$7,435.33	$3,393.39
Total	-	$1,318,923.33	$601,939.39

Salvage Values

Salvage Year 2030

Cost Information -- Using NPV on a basis of total costs for one direction

Phase	Description	Source	Salvage Value	Net Value
Initial Construction	-	DARWin Calculated	$0.00	$0.00
Rehabilitation #1	-	DARWin Calculated	$0.00	$0.00

Initial Construction Maintenance Costs

Year Maintenance Costs Begin	2001
Annual Maintenance Costs	$50.00 per lane mi
Annual Increase in Maintenance Costs	0 %

Calculated Non Discounted Maintenance Costs (One Direction) $13,133.94

Rehabilitation #1 Maintenance Costs

Year Maintenance Costs Begin	2021
Annual Maintenance Costs	$50.00 per lane mi
Annual Increase in Maintenance Costs	0 %

Calculated Non Discounted Maintenance Costs (One Direction) $7,435.33

Initial Construction Pay Items

Name	Lane	Layer	Unit	Unit Cost	Quantity	Total Cost
12 " PCCP	T.L.	1	sq yd	$30.00	222,933	$6,688,000.00
10% for preliminary engineering	T.L.	1	lump sum	$668,800.00	1	$668,800.00
12% for const. engineering	T.L.	1	lump sum	$802,560.00	1	$802,560.00
15% for Traffic Control	T.L.	1	lump sum	$1,003,200.00	1	$1,003,200.00
Workzone User Cost	T.L.	1	lump sum	$501,183.00	1	$501,183.00

Non Discounted Costs (One Direction)

Traffic Lane	$9,663,743.00
Inner Shoulder	$0.00
Outer Shoulder	$0.00
Miscellaneous	$0.00

Total Non Discounted Cost (One Direction) $9,663,743.00

Rehabilitation #1 Pay Items

Name	Lane	Layer	Unit	Unit Cost	Quantity	Total Cost
Diamond Grinding - Hard Agg	T.L.		sq yd	$5.00	140,800	$704,000.00
Full-Depth Repair 1,408 sq. yds. @ $6....	T.L.	2	lump sum	$109,824.00		$109,824.00
10% for preliminary engineering	T.L.		lump sum	$81,382.00	1	$81,382.00
12% for const. engineering	T.L.		lump sum	$97,659.00		$97,659.00
15% for Traffic Control	T.L.		lump sum	$122,074.00		$122,074.00
Workzone User Cost	T.L.		lump sum	$196,549.00		$196,549.00

Non Discounted Costs (One Direction)

Traffic Lane	$1,311,488.00
Inner Shoulder	$0.00
Outer Shoulder	$0.00
Miscellaneous	$0.00
Total Non Discounted Cost (One Direction)	$1,311,488.00

Initial Construction -- Traffic Lane Dimensions

Layer	Material Description	Width (ft)	Thickness (in)
	12" PCCP	38	12

Initial Construction -- Inner Shoulder Dimensions

Material Description	Width (ft)	Inner Thickness (in)	Outer Thickness (in)

Initial Construction -- Outer Shoulder Dimensions

Material Description	Width (ft)	Inner Thickness (in)	Outer Thickness (in)

	INPUT DATA		
Project Name	Bethune		
Freeway Name	I-70		
Input File	...DOT\BETHUNE.WZM		
Project Start Date			
Project End Date			
Design Speed	75 mph		
Speed Limit	75 mph		
Workzone Speed Limit	65 mph		
Grade	2.0 %		
Work Zone Length	10.00 miles		
Functional Class	Rural Interstate (Weekday)		
INBOUND		**OUTBOUND**	
Total Number of Lanes	2	**Total Number of Lanes**	2
Number of Open Lanes	1	**Number of Open Lanes**	1
Number of Temporary Lanes	0	**Number of Temporary Lanes**	0
AADT	3925	**AADT**	3925
Percentage of Single Unit Trucks	8.3 %	**Single Unit Trucks(%)**	8.3 %
Percentage of Combination Trucks	30.2 %	**CombinationTrucks(%)**	30.2 %
	OUTPUT SUMMARY		
	ADDITIONAL USER COST DUE TO WORKZONE		
TYPE OF WORK	**INBOUND COST**	**OUTBOUND COST**	**DURATION**
412-Concrete Pavement <= 14.0 inc	$250,591.55	$250,591.55	100
TOTAL ADDL. USER COST	$250,591.55	$250,591.55	100
TOTAL USER COST FOR NORMAL CONDITION (WITH NO WORKZONE)			
FOR A DURATION OF 100 DAYS : INBOUND = $3,652,256.19 OUTBOUND = $3,652,256.19			
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	INPUT DATA	
Project Name	Bethune	
Freeway Name	I-70	
Input Filename	C:\CDOT\BETHUNE2.WZM	
Project Start Date		
Project End Date		
Design Speed	75 mph	
Speed Limit	75 mph	
Workzone Speed Limit	45 mph	
Grade	2.0 %	
Work Zone Length	10.00 miles	
Total Number of Lanes	2	
Number of Open Lanes	1	
Number of Temporary Lanes	0	
AADT, Directional	3925	
Percentage of Single Unit Trucks	8.3 %	
Percentage of Combination Trucks	30.2 %	
Functional Class	Rural Interstate (Weekday)	
	OUTPUT SUMMARY	
TYPE OF WORK	ADDITIONAL USER COST DUE TO WORKZONE	DURATION
202-Removal of Concrete (Diamond Grinding)	$196,549.08	30
TOTAL ADDL. USER COST	$196,549.08	30
TOTAL USER COST FOR NORMAL CONDITION (WITH NO WORKZONE)		
FOR A DURATION OF 30 DAYS = $634,865.02		
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