CHAPTER 2

PAVEMENT ISSUES

2.1 Reserved.

2.2 Reserved.

2.3 Tire Pressure, Technical Paper 89-001, February 15, 1989.

2.4 Reserved.

2.5 A Discussion of Discount Rates for Economic Analysis of Pavements, February 1990.

2.6 Resilient Modulus Testing Equipment, February 24, 1988.

2.7 Longitudinal Joint Construction and Edge Drop-Offs, March 1989.

2.8 Reserved.

2.9 Reserved.

2.10 Life Cycle Cost Analysis, September 15, 1992.
- Interim Policy Statement - FR, July 11, 1994.

2.11 Reserved

2.12 ISTEA Implementation Interstate Maintenance Program, Memorandum, May 21, 1992.

2.13 Preventive Maintenance, July 27, 1992.
- Information on Interstate Maintenance Program, June 14, 1993.

2.14 Computer Software
- McTran's Software, July 1995.

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: Technical Paper 89-001 - Tire Pressure

Date: FEB 15 1989

From: Chief, Pavement Division
Washington, D.C. 20590

Reply to Attn of: HHO-11

To: Regional Federal Highway Administrators
Direct Federal Program Administrator

The effects of increased tire pressure on pavement performance has been a topic of considerable discussion during the past several years. The attached "Technical Paper" is issued to provide FHWA field engineers with the 'latest information on trends in tire pressures, and tire pressure effects on pavement performance. The paper's format consists of a series of questions and answers to the most commonly asked questions on this subject.

Two copies of the paper are attached for your use and handling. Please make distribution to the division offices following your normal distribution process.

Additional information on the effects of tire pressure on pavement performance may be obtained by contacting the Pavement Division, Pavement Management Branch at FTS 366-1337.

for Louis M. Papet

Technical Paper 89-001 - Tire Pressure

The purpose of this technical paper is to provide pavement specialists with the latest information regarding trends in tire pressures and the effects of increased tire pressure on pavement performance. The format consists of questions and answers to four of the most commonly asked questions by pavement engineers.

1. Has there been an increase in tire inflation pressure since the AASHO Road Test?

   Cold inflation pressures for tires used at the AASHO Road Test conducted between 1958 and 1960, were 75 psi for the 7.5 to 11-inch tires and 80 psi for the 12-inch bias ply tires. The'tire pressures are recommended cold inflation pressures for specified wheel loads, ranging from about 3000 pounds for the 7.5-inch tires to about 6800 pounds for a 12.00x24-inch tire. Hottirepressures were typically 9 to 20 psi higher than the cold pressures and averaged 11 psi higher. Hot tire pressures for the heavier wheel loads would therefore have averaged about85 to 90 psi although pressures from 23 to 130 psi were reported. It was noted at the Road Test that tire pressures increased graduallywith truck operationbut stabilized after 90 minutes.

   A 1987 nationwide tire pressure survey cooperatively done by the FHWA and State motor carrier safety organizations, showed that 81 percent of the 5040 hot tire pressures measured fell in the range of 85 to 115 psi. While the size and type of tire was not recorded in this survey, it is estimated that 70 percent of the tires were radials. Contactwith tire manufacturers indicate that75 percent of all trucktires now sold are steel-belted radials with recommended cold inflation pressures of 95 to 100 psi.

   Tire pressure surveys done in Canada, Florida, Illinois, Kentucky, New Mexico, and Oregon, in 1985 and 1986, involving more than 4000 trucks showed average hot radial tire pressures of between 96 and 107 psi.

   Itshouldbe noted that radial tire pressures are approximately 5 psi higher than bias ply tire pressures for the same wheel load. While radial tires flex more during operation, less heat is generated due to their radial ply construction. To compensate for the lower operating temperature of radial tires, manufacturers recommend higher inflation pressure which reduces tire deflection, and equalizes the footprint between radials and bias ply tires.

   The Wisconsin Department of Transportation did a detailed survey of 6780 truck tires in 1987 that showed 93 percent of hot tire pressures fell between 85 and 115 psi. The average hot tire pressure was about 100 psi. Wisconsin found that 12 percent of tractor semitrailer tires were overinflated and14 percent were underinflated. In the national survey sponsored by FHWA, 11 percentwere overinflated and 19 percent were underinflated. Over- and underinflation were defined as plus or minus

10 psi with respect to the tire manufacturer's recommended inflation pressure. Ran this information, it does not appear that truck drivers are intentionally overinflating their tires.

The most common tire size reported in the Wisconsin survey was an U-inch tire on a 24.5-inch rim followed by an ll-inch tire on a 22.5-inch rim.

The Tire and Rim Association publishes recommended tire sizes and maximum cold inflation pressures for various tire loads. A comparison of recommended tire pressures for the years 1930, 1969, and 1985 show only modest increases in inflation pressure for given loads. For example, the recommended tire pressure for a 10-inch tire to carry 4000 pounds is 65 psi for all 3 years. The recommended tire pressure for a ll-inch tire to carry 5000 pounds was 70 psi in 1930, and 80 psi in 1969 and 1985. For a 6000-pound load on a 12-inch tire, the recommended inflation pressure was 80 psi in 1930 and 90 psi in 1969 and 1985.

The 1974 Highway Act raised the single axle maximum weight limit fran 18,000 pounds to 20,000 pounds, the tandem axle weight limit from 32,000 pounds to 34,000 pounds, and established a maximum gross weight limit of 80,000 pounds. These increases in allowable weight limits have resulted in gradually increasing truck weights and 18,000-pound equivalent single axle loads. For example, on the rural Interstate System, the average number of equivalent single axle loads has been increasing about 7 percent per year, between 1970 and 1985. A recent study by Texas A&M University entitled "Improved Prediction of EAL" suggests that this increase is due to use of larger trucks rather than an increase in truck loads.

In conclusion, tire pressures for given load rated tires have not changed much over the last 50 years. Due to the increase in load being carried and the use of radial tires, fleet tire pressures have increased about 10 to 20 psi when compared to tire pressures at the AASHO Road Test.

2. Does an increase in tire pressure accelerate pavement deterioratim?

There are six recent Studies that suggest flexible pavement deterioration is accelerated by increased tire pressure. This is especially true for thin pavements, i.e., AC surface course 1 to 3 inches in thickness. The six studies were done at the Universities of Kentucky, Munich, Texas, and Waterloo (Canada), and at the Massachusetts Institute of Technology and Texas A&M university. These studies are summarized in NCHRP l-25, "Effects of Heavy Vehicle Characteristics on Pavement Response and Performance." Brief extracts fmn the six studies are as follows:

Kentucky: A distress model was developed to predict loads to fatigue failure. It was determined that the load equivalency factor increased rapidly with increasing tire contact pressure and decreasing pavement thickness. Damage at 120 psi was 5.5 times greater than at 75 psi for thin AC pavements.

Munich: Rutting rate versus tire pressure for single and dual tires was studied. Rut depth doubled when tire pressure was increased fran 100 to 130 psi.

Texas: Strain increased significantly in 1-2" AC pavements as tire pressure was increased fran 75 to 110 psi. The increase in tire pressure resulted in a 25 percent decrease in pavement life.

Waterloo: An increase in tire pressure from 60 to 120 psi increased strain in the AC surface course and top of the subgrade causing fatigue cracking. A seven fold increase in rut formation was predicted for the same increase in tire pressure.

MIT: Damage at 125 psi is more than two times greater than the damage at 75 psi for 1-3" AC pavements. The time to rutting failure was reduced by 30 percent, and surface rutting increased 300 percent for a tire pressure increase from 75 to 125 psi.

Texas A&M: There was a 50 percent decrease in fatigue life of a 2-inch AC pavement over 8 inches of aggregate base when the tire pressure was increased from 75 to 125 psi. The higher tire pressure substantially increased the rate of fatigue cracking in the thin AC surface.

It should be emphasized that the above results are for thin AC pavements (1-3 inches of AC) and are based on computer models and not on field surveys.

At the FHWA's accelerated loading facility (ALF) in Virginia, the effects of tire pressure were evaluated on a flexible pavement consisting of 2 inches of asphalt concrete wearing course, 5 inches of asphalt concrete binder course and 12 inches of crushed aggregate base course constructed on an AASHTO A-4 subgrade. Tire pressures of 76 and 140 psi and both radial and bias ply tires were used in the study. A second variable in the study was dual wheel load set at 9400 and 19,000 pounds. Surface deflection and strain and tensile strain at the bottom of the AC layer were measured.

Results show that doubling the load from 9400 pounds to 19,000 pounds on this thick pa-t section increased predicted pavement damage by 1000 percent, while doubling the tire pressure increased predicted damage by only 20 percent. It was quite obvious that for this pavement section increasing wheel load affected the pavement considerably more than increasing tire pressure. Predicted pavement damage was in terms of fatigue equivalency factor developed using an exponential relationship between the number of cycles to failure and the magnitude of the tensile strain at the bottom of the asphalt layer.

While it is safe to say that wheel loads affect the pavement considerably more than tire pressures, care should be exercised in making judgments about the effect of load and tire pressures on real trafficked pavement sections. The ALF does not duplicate actual truck wheel loads in that ALF does not have a suspension system equivalent to a truck suspension system. Loads are also not applied to the pavement in the same manner as under actual highway conditions.

One other finding of interest related to tire pressure is from an Australian study as summarized in NCHRP 1-25. It was found that dynamic load induced by the drive wheels of a tractor semitrailer truck decreased with an increase in tire pressure. Tire pressure did not, however, affect dynamic load induced by the trailer wheels. This finding is contrary to a study done by the Massachusetts Institute of Technology which found that an increase in tire pressure from 75 to 120 psi increased the dynamic load coefficient from 0.12 to 0.14. Dynamic load coefficient is defined as the standard deviation of the dynamic load divided by the mean dynamic load.

3. What efforts have been made to assess tire pressure trends and quantify the impacts on flexible pavements?

The most significant effort to assess *tire pressure trends* and to define the extent of the tire pressure problem, was a 1-day symposium held in the spring of 1987 in Austin, Texas. The symposium which was sponsored by AASHTO and the FHWA was attended by 70 individuals representing the highway, tire, and trucking industries. Questions used to guide the discussion included: Has there been an increase in tire pressure since the AASHO Road Test? Has increased tire pressure accelerated pavement damage? Is legislation needed to regulate new tire and truck designs? Is it time to accelerate our efforts to improve mix design? Should load equivalency factors be increased?

Findings from the symposium are reflected in the answers to our first two questions. It was generally agreed that the introduction of legislation was not an appropriate course of action at this time to regulate new tire and truck designs. Such legislation would also be very difficult and costly to monitor and enforce. A legislated solution to the effects of tire pressure should be a last resort approach.

Those in attendance thought that efforts to improve mix design should be accelerated and that load equivalency factors should be increased. It was felt that better communication between segments of the transportation industry and more research are needed to define the relationship between vehicle characteristics and pavement deterioration.

The Second North American Conference on Managing Pavements was held in Toronto, Canada November 2-6, 1987. At this conference papers were presented on all aspects of pavement management including impacts of trucks. Mr. Jack Friedenrich, Chairman of the AASHTO Task Force on High Pressure Truck Tires, presented a paper summarizing the Task Force's work to date. In addition to discussing trends in truck tire design and inflation pressure, Mr. Friedenrich outlined the pavement problems resulting from higher tire pressures and discussed an approach and needed research to solve these problems.

Tire pressure and related pavement problems are not solely those of increased rate of pavement deterioration. The AASHTO pavement design equations are based on a set of assumptions including the assumption that today's tire pressures are the same as those at the Road Test. Because we have shown that today's tire pressures are higher and because other assumptions about environment, roadbed soils, vehicle characteristics, etc. may have not been met, the design and analysis of pavement structures using AASHTO procedures are being questioned. The basic AASHTO design equations are also being questioned due to changes in allowable axle loads, suspension systems, wheel configurations, and axle spacing since the Road Test.

Finding a solution to the problem of increased rate of pavement deterioration is not easy because of the number of factors that contribute to the problem. For this reason, the solution must involve all aspects of the complex relationship between vehicle and pavement. Models that incorporate all vehicle characteristics need to be developed and verified so that accurate dynamic loads applied to the pavement can be determined. Pavement models that predict the number of load applications to a particular type of pavement failure also need to be developed and verified.. When we can confidently predict the effects of changes in vehicle characteristics and pavement design, we can begin making those decisions which will give us the longest pavement life for the least cost.

The solution to the problem also involves a continuing dialogue among those building the pavements, those using our highways, and tire and truck manufacturers. Toward that end, Mr. Friedenrich suggested future symposiums like the one held in Austin, Texas.

There were two tire pressure-related papers presented at the 1988 Transportation Research Board annual meeting in Washington, D.C. The first paper is entitled: "Effect of Load, Tire Pressure, and Type on Flexible Pavement Response" by Messrs. Ray Bonaquist, Charles Churilla, and Ms. Deborah Freund of the Federal Highway Administration. The paper presents the findings of work with the FHWA's accelerated loading facility for the first two pavement sections tested. These findings are included in the answer to the second question.

The second paper is entitled: "Evaluation of Increased Pa-t Loading and Tire Pressure" by Stuart Hudson and Stephen Seeds of Austin Research Engineers, Inc. (ARE). The authors summarize work done for the Arizona Department of Transportation to develop computer programs to calculate 18,000-pound equivalent single axle loads (ESAL's) from both loadometer and weigh-in-motion data. The programs have the capability of using either AASHTO load equivalency factors or factors developed by ARE. The ARE load equivalency factors take into consideration tire pressure, pavement structure, truck classification, wheel configuration, and axle configuration. Based on the results of a survey of 350 trucks in Arizona, the authors believe that tire pressure should be included in flexible pavement design. The survey showed that the average hot tire pressure for the tires on the truck steering axle to be 106 psi, and 102 psi for the tires on the drive and trailer axles. The values are about 20 percent higher than the 85 to 90 psi hot tire pressures measured at the AASHO Road Test. Using a fatigue damage model developed by Mr. Fred Finn and a pavement section composed of 3 inches of AC over 6 inches of aggregate base and 8 inches of aggregate subbase, the authors concluded that an increase in tire pressure fran 90 psi to 121 psi would reduce pavement life by 38 percent. Ninety percent of the tire pressures measured in the Arizona survey fell in the range of 90 to 121 psi. The shortened pavement life due to increased tire pressure is the reason the authors believe that load equivalency factors used to design pavement structures should consider tire pressure. The tire pressure adjusted load' equivalency factor would equal the loads to a particular type of pavement failure or amount of damage for a standard wheel load and tire pressure divided by the number of loads to the same pavement failure or amount of damage for a given wheel load and tire pressure.

4. What can be done to make flexible pavements more resistant to tire pressure-related damage?

Tire pressure is crucial in determining stresses near the surface of a flexible pavement. High tire pressures, thus, necessitate high-quality materials in the upper layers of the flexible pavement. Asphalt overlays of concrete pavements may also be highly impacted by increased contact pressures.

The same preliminary design, mix design, construction, and maintenance practices that have been used to make flexible pavements more resistant to rutting, stripping, and cracking can also be applied to ensuring AC pavements are resistant to higher tire pressures. These practices can be found in FHWA Technical Advisory T5040.27, "Asphalt Concrete Mix Design and Field Control," March 10, 1988, and in such study reports and manuals as the following:

"Asphalt Pavement Rutting Western States," Western Association of State Highway and Transportation Officials, original report, May 1984, and followup report, February 1988.

"Asphalt Pavement Rutting and Stripping Report," FHWA Ad Hoc Task Force, August 14, 1987.

"Hot-Mix Bituminous paving Manual," FHWA, May 1984.

Some important factors brought out by this paper and by the referenced materials which may help prevent failures under high tire pressure conditions are as follows:

(1) Use the FHWA Traffic Monitoring Guide and weigh-in-motion (WIM) equipment to obtain accurate design axle loadings.

(2) Follow the recommendations found in the FHWA Technical Advisory T5040.27 "Asphalt Concrete Mix Design and Field Control" with particular emphasis on the suggested eight steps to be followed in pavement rehabilitation design.

(3) Stripping is often a primary cause of rutting which is aggravated by high tire pressures. Be sure to consider an anti-strip additive when high volumes of trucks are anticipated.

(4) Use the 0.45 power gradation chart to select the proper aggregate gradation for optimum mix density, stability, and voids.

(5) Follow recommended good engineering procedures pertaining to drainage, site control, choice of asphalt, choice of aggregate, mix design; base and subbase design, plant operation, construction practices, quality control, and maintenance.

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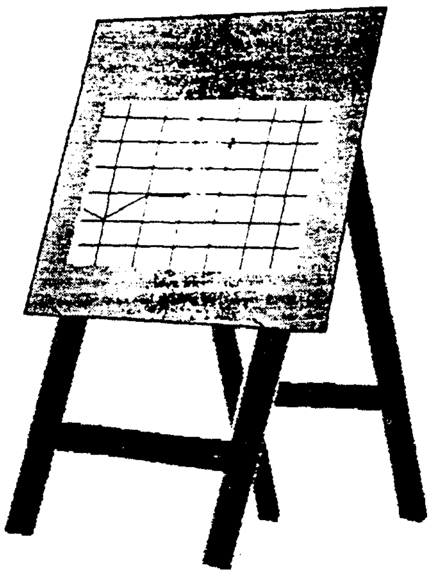
A DISCUSSION OF

DISCOUNT RATES FOR ECONOMIC ANALYSIS OF PAVEMENTS



by

Peter Z. Kleskovic

Highway Engineer

FHWA

Pavement Division

Feburary 1990

DRAFT

A DISCUSSION OF DISCOUNT RATES FOR ECONOMIC ANALYSIS OF PAVEMENTS

PETER Z. KLESKOVIC

GENERAL

In a life cycle cost analysis, a discount rate is needed to compare costs occurring at different points in time. The discount rate reduces the impact of future costs on the analysis, reflecting the fact that money has a time value. In the private sector, money that is not spent today can be invested to earn some rate of return. In the public works sector, where needs usually exceed the available funds, savings from one project can be used to build another project. This results in additional benefits to the public.

The factors that determine interest rates for bonds include inflation, risk, liquidity and tax liabilities. Removing these factors should result in a real interest rate that represents the true time value of money. In the engineering economics literature, this rate is known as the discount rate.

There continues to be discussion about what rate to use when evaluating alternative pavement strategies. In a 1987 survey, State Highway Agencies used rates ranging from 0 to 9 percent. Of the 27 responses, the median discount rate was 4 percent, which was used by 26 percent of the responding States. In total, 59 percent of the responding States used a discount rate in the range of 3 to 5 percent, with 19 and 22 percent either below or above this range, respectively.

The discount rate can affect the outcome of a life cycle cost analysis in that certain alternatives may be favored by higher or lower rates. High rates favor alternatives that stretch out costs over a period of time, since the future costs are discounted in relation to the initial cost. A low rate hurts these alternatives since future costs are added in at almost face value. In the case of a discount rate equal to 0, all costs are treated equally regardless of when they occur. Where alternative strategies have similar maintenance, rehabilitation and operating costs, the discount rate will have a minor effect on the analysis and initial costs will have a larger effect.

This paper documents a review and analysis of economic data in order to determine an appropriate discount rate to use in economic analyses of pavements. Interest and inflation data was assembled for the period of 1950 to 1987. Discount rates were then computed by subtracting the inflation rates for each year from the corresponding interest rates. Most of the interest and inflation data was obtained from the Economic Report of the President, February 1988. The Producer Price Index data came from the Handbook of Cyclical Indicators. The Federal-aid Price Index data came from the 1st Quarter 1974 and the 3rd Quarter 1987 'Price Trends for Federal-Aid Highway Construction.'

INTEREST RATES

Table 1 presents six interest rates between 1950 and 1987. They are:

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YEAR	3 YEAR TREASURY BONDS	BANK PRIME RATE	Aaa CORP BONDS	Baa CORP BONDS	HIGH GRADE MUNICIPAL BONDS	FEDERAL FUNDS RATE.
1950		2.1	2.6	3.2	2.0	
51		2.6	2.9	3.4	2.0	
52		3.0	3.0	3.5	2.2	
53	2.5	3.2	3.2	3.7	2.7	
54	1.6	3.1	2.9	3.5	2.4	
55	2.5	3.2	3.1	3.5	2.5	1.8
56	3.2	3.8	3.4	3.9	2.9	2.7
57	4.0	4.2	3.9	4.7	3.6	3.1
58	2.8	3.8	3.8	4.7	3.6	1.6
59	4.5	4.5	4.4	5.1	4.0	3.3
1960	4.0	4.8	4.4	5.2	3.7	3.2
61	3.5	4.5	4.4	5.1	3.5	2.0
62	3.5	4.5	4.3	5.0	3.2	2.7
63	3.7	4.5	4.3	4.9	3.2	3.2
64	4.0	4.5	4.4	4.8	3.2	3.5
65	4.2	4.5	4.5	4.9	3.3	4.1
66	5.2	5.6	5.1	5.7	3.8	5.1
67	5.0	5.6	5.5	6.2	4.0	4.2
68	5.7	6.3	6.2	6.9	4.5	5.7
69	7.0	8.0	7.0	7.8	5.8	8.2
1970	7.3	7.9	8.0	9.1	6.5	7.2
71	5.7	5.7	7.4	8.6	5.7	4.7
72	5.7	5.3	7.2	8.2	5.3	4.4
73	7.0	8.0	7.4	8.2	5.2	8.7
74	7.8	10.8	8.6	9.5	6.1	10.5
75	7.5	7.9	8.8	10.6	6.9	5.8
76	6.8	6.8	8.4	9.8	6.5	5.0
77	6.7	6.8	8.0	9.0	5.6	5.5
78	8.3	9.1	8.7	9.5	5.9	
79	9.7	12.7	9.6	10.7	6.4	1::;
1980	11.6	15.3	11.9	13.7	8.5	13.4
81	14.4	18.9	14.2	16.0	11.2	16.4
82	12.9	14.9	13.8	16.1	11.6	12.3
83	10.5	10.8	12.0	13.6	9.5	9.1
84	11.9	12.0	12.7	14.2	10.2	10.2
85	9.6	9.9	11.4	12.7	9.2	8.1
86	7.1	8.3	9.0	10.4	7.4	
87	7.7	8.2	9.4	10.6	7.7	6.8 6.7
1950-87	6.4[a]	7.0	6.8	7.8	5.3	6.3[a]
1950-59	3.0[a]	3.4	3.3	3.9	2.8	2.5[a]
1960-69	4.6	5.3	5.0	5.7	3.8	4.2
1970-79	7.2	8.1	8.2	9.3	6.0	7.1
1980-87	10.7	12.3	11.8	13.4	9.4	10.4

a. Average is for period of available data.

Table 1. Interest Rates (1950 - 1987)

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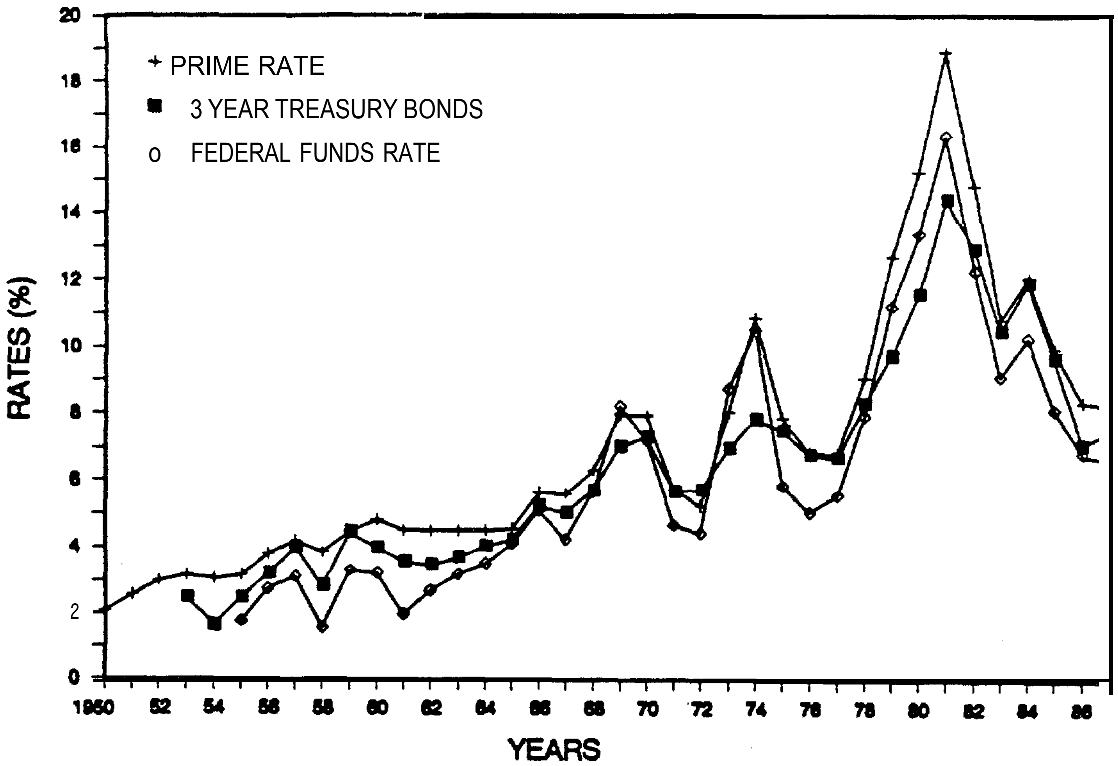

Figure 1. Three interest Rates

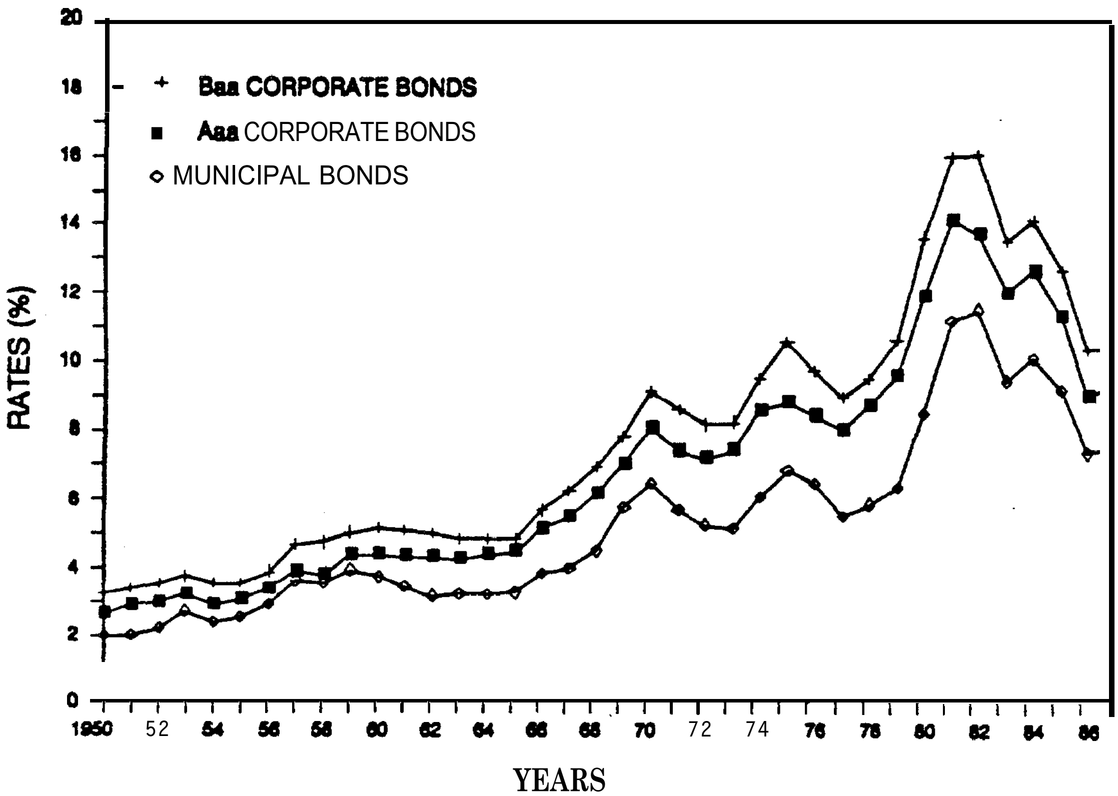

Figure 2. Three Interest Rates

Treasury Bonds (3 Years): Securities backed by the taxing power of the US Government and exempt from State and local taxes.

Bank Prime Rate: The rate banks charge their most credit worthy customers for short term loans.

Aaa Corporate Bonds (Moody's): Highest graded bonds.

Baa Corporate Bonds **(Moody's):** Lower medium graded bonds.

High Grade **Municipal** Bonds (S&P): Bonds of states, cities, or counties. They are often exempt from federal, state and local taxes.

Federal Funds Rate: The interest rate on overnight loans between banks.

These six rates are plotted on Figures 1 and 2. For clarity, only three rates are shown on each figure. Although, the individual rates vary, all follow a similar pattern. Of the six interest rates, the Baa corporate bond usually was the highest. The fairly consistent difference between Baa and Aaa bonds is a measure of the higher risk that Baa bonds carry. Treasury and municipal bond rates are usually lower than the two corporate bonds or the prime rate, again because of their lower risk. Municipal bonds usually have lower rates than Treasury bonds, because of their generally tax exempt status.

Figure 3 is a plot of the high, average, and low value of the six rates for each year. In 1950, these rates ranged from 2 to 3.2 percent. They rose at a slow rate till about 1965, when the range was from 3.3 to 4.9. Since then,

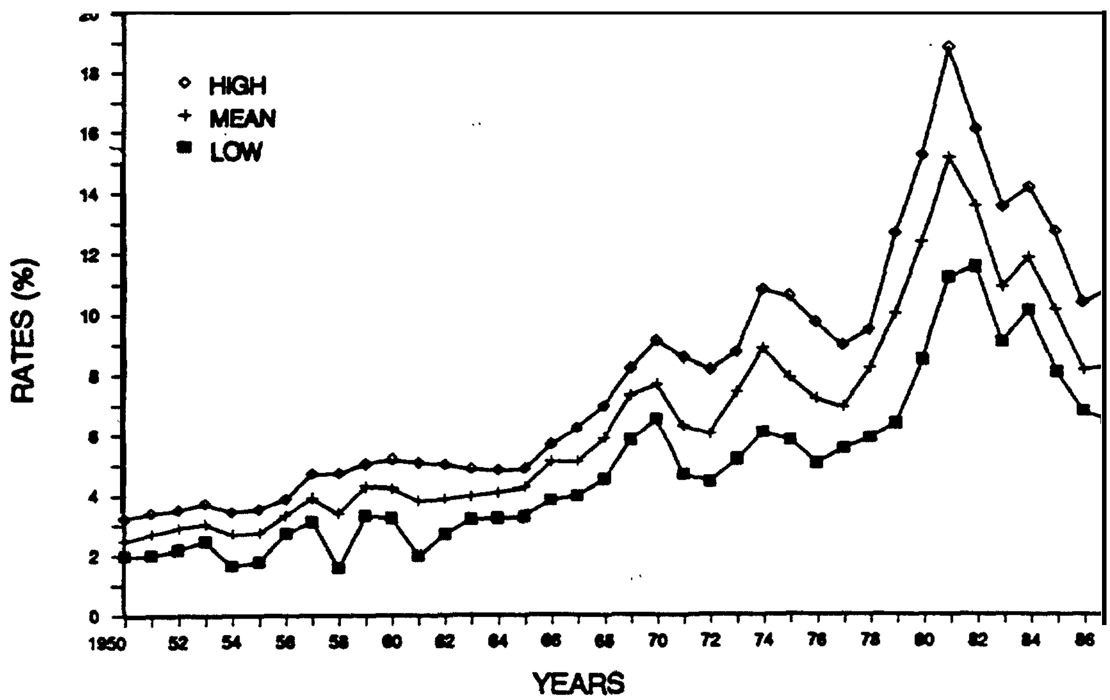

Figure **3. High/Low** Range of Six Interest Rates

rates have peaked three times, 1970, 1974 and 1981. In 1981, rates reached their highest peak in recent times, ranging from 11.2 to 18.9 percent, and averaging 15.2 percent. These rates have dropped since this peak, with a range of 6.7 to 10.6 percent and an average value of 8.4 percent in 1987.

INFLATION RATES

Table 2 presents inflation rates as measured by the year to year rate of change in four indexes. They are:

Implicit G.N.P. Price Deflator: Index of average price level of all final goods and service. Used to convert current-dollar GNP to constant-dollar GNP.

Composite Index (FHWA): Index composed of six indicator items including excavation, pavement surfaces and structural elements. These are reported in the "Price Trends for Federal-aid Highway Construction."

Consumer Price Index: Measure of the average level of prices over time in a fixed market basket of goods and services.

-Producer Price Index (all commodities): Measures average changes in prices received by commodity producers.

Figure 4 plots the yearly rate of change for three of the inflation indexes from 1950 to 1987, the Implicit G.N.P. Price Deflator, the Consumer Price, Index, and the Producer Price Index. The three inflation rates show similar trends to the interest rate curves. During most of the 1950's and early 1960's, inflation rates were low, generally below 4 percent. Inflation started to rise during the mid 1960's and into the early 1970's. Major increases in inflation occurred in 1973-1974 and during the late 1970's. Inflation rates have generally fallen since 1980. The Producer Price Index is the most volatile of the three rates on Figure 4, generally having either the lowest or the highest yearly rates of change.

The rate of change in the Composite Index from the 'Price Trend for Federal-aid Highway Construction" is shown on Figure 5. Although, this index tracks the other inflation indexes it fluctuates over a much wider range.

DISCOUNT RATES

Discount rates were computed from the above data by subtracting the inflation rates from the interest rates for each year. Since data was assembled for six different interest rates and four inflation rates, there are twenty-four possible discount rates that could be considered. To make this effort more manageable, only nine discount rates were computed using the following combinations of interest and inflation rates:

Xnterest Rates	Inflation Rates
Treasury Bonds (3 Years)	Implicit G.N.P. Deflator
Aaa Corporate Bonds	Consumer Price Index
Municipal Bonds	Composite Index (FHWA)

YEAR	IMPLICIT GNP PRICE DEFLATOR	COMPOSITE INDEX (FHWA)	CONSUMER PRICE INDEX	PRODUCER PRICE INDEX COMMODITIES
	2.0		1.0	3.9
1951	4.8		7.9	11.4
52	1.5	2.8	2.2	-2.7
53	1.6	-5.7	0.8	-1.4
54	1.6	[illegible]	0.5	0.2
55	3.2	-2.8	-0.4	0.2
56	3.4	13.1	1.5	3.3
57	3.6	4.4	3.6	2.9
58	2.1	-2.4	2.7	1.4
59	2.4	-4.2	0.8	0.2
60	1.6	-2.3	1.6	0.1
61	1.0	0.8	1.0	-0.4
62	2.2	3.8	1.1	0.3
63	1.6	2.3	1.2	-0.3
64	1.5	0.8	1.3	-0.2
65	2.7	3.7	1.7	2.0
66	3.6	6.5	2.9	3.3
67	2.6	4.1	2.9	0.2
68	5.0	3.5	4.2	2.5
69	5.6	8.2	5.4	3.9
70	5.5	12.2	5.9	3.7
71	5.7	4.8	4.3	3.3
72	4.7	5.1	3.3	4.5
74	6.5	10.3	6.2	13.1
75	9.1	36:0	19.1	18.9
	9.8	0.4		9.2
76	6.4	-3.4	5.8	4.6
77	6.7	7.1	6.5	6.1
78	7.3	19.4	7.7	7.8
79	8.9	19.4	11.3	12.6
80	9.0			
81	9.7	-3.9 14.3	10.4 13.5	14.1
82	6.4		6.1	9.2
83	3.9	-0.2 -6.3	3.2	2.0
84	3.7	5.8	4.3	
85	3.2	11.0	3.6	
86	2.6	-0.3	1.9	
87	3.0		3.7	
		5.2		
1950-87	4.4	2.7	4.3	4.2 a
	2.6		2.1	1.9
1950-59	2.7	3.1 a	2.3	1.1
1960-69	7.1	11.1	7.1	8.4
1980-87	5.2	2.9	5.8	8.4 a

a. Average is for period of available Qtr.

Table 2. Yearly Inflation Rates (1950-1987)

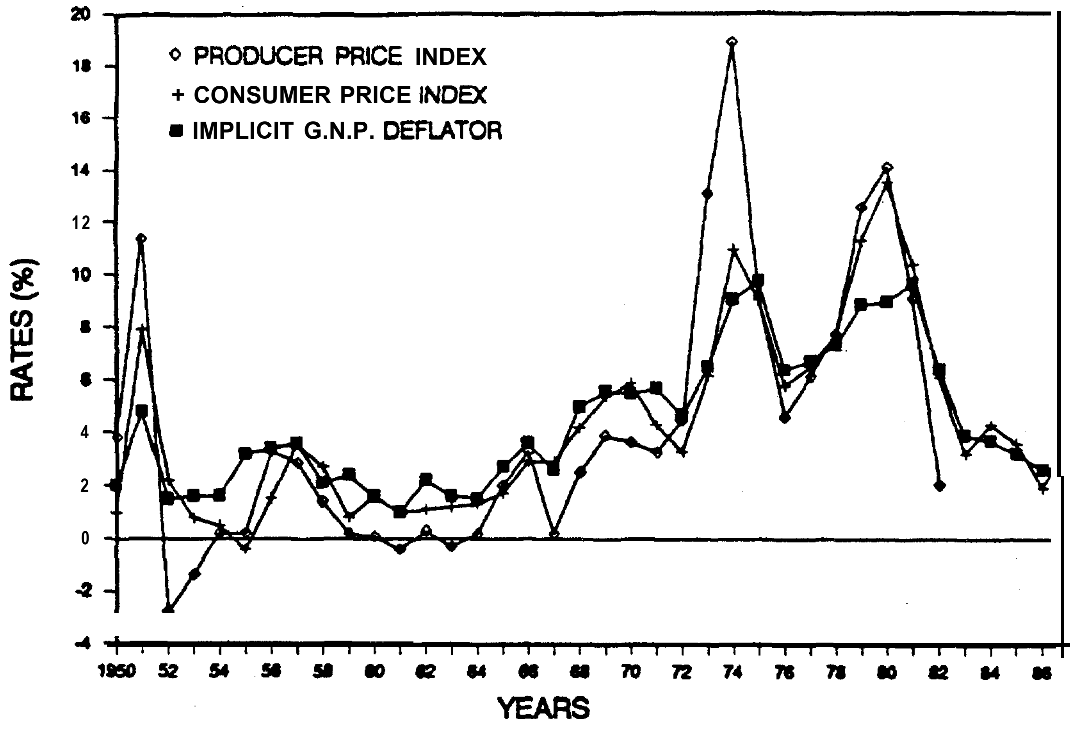

Figure 4. Year to Year Rate of Change in Three Inflation Indexes.

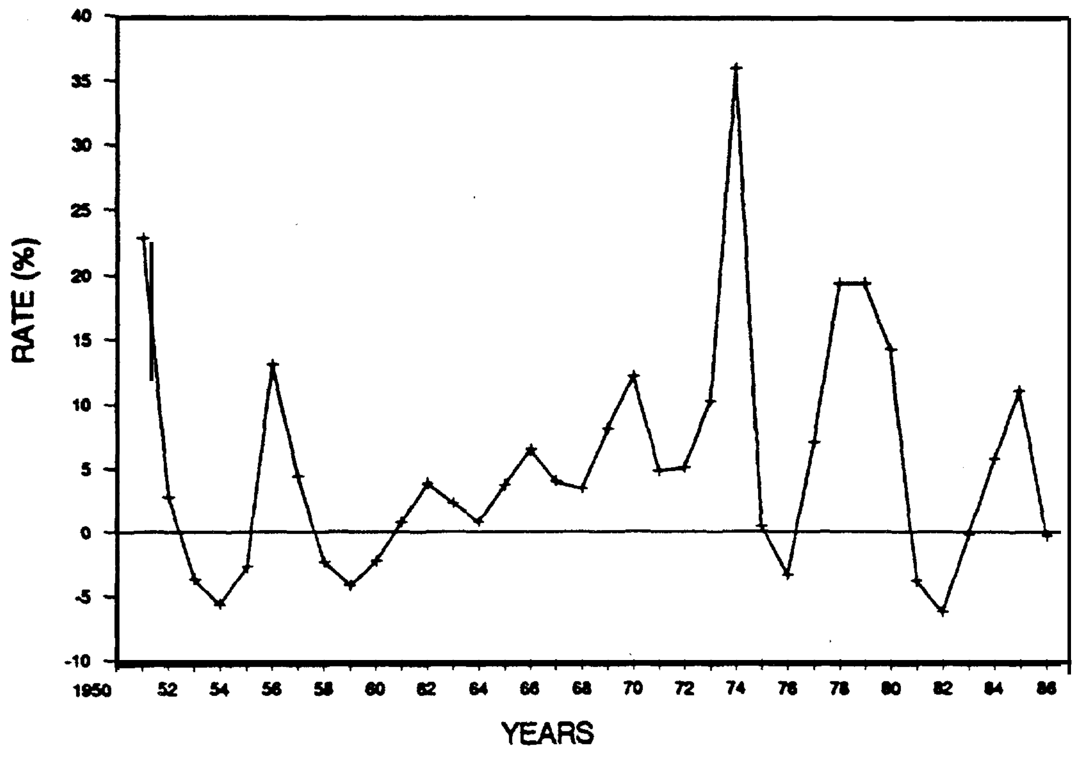

Figure 5. Year to Year Rate of Change in Composite Index (FHWA)

It is recognized that the discount rates computed from these sets of data may not be the most theoretically appropriate for an analysis of pavements. The purpose was to determine if discount rates varied over time or if they held fairly constant.

It was expected that the different discount rates would generally follow parallel paths over time, but that individual curves would be higher or lower based on other factors, such as, risk. The three interest and three inflation rates that were used in the analysis were chosen because they were less volatile than the other rates. The exception was the Composite Index (FHWA) which is highly volatile, but was used in the analysis because of its relationship to the highway program.

The nine discount rates are plotted in figures 6, 7 and 8. The six curves in Figures 6 and 7 followed similar tracks with time. The curves on Figure 8, which are based on the Composite Index (FHWA), follow similar paths but with highly exaggerated movements. The inflation component of the discount rates on Figure 8 completely overpower the effect of the different interest rates.

Figures 6 and 7 show that the discount rate is not fixed over time. The 1960's are the only period in recent times where discount rates remained fairly constant and relatively low. During the **1970's,** discount rates were very unsteady due to the surges in inflation that occurred during the middle

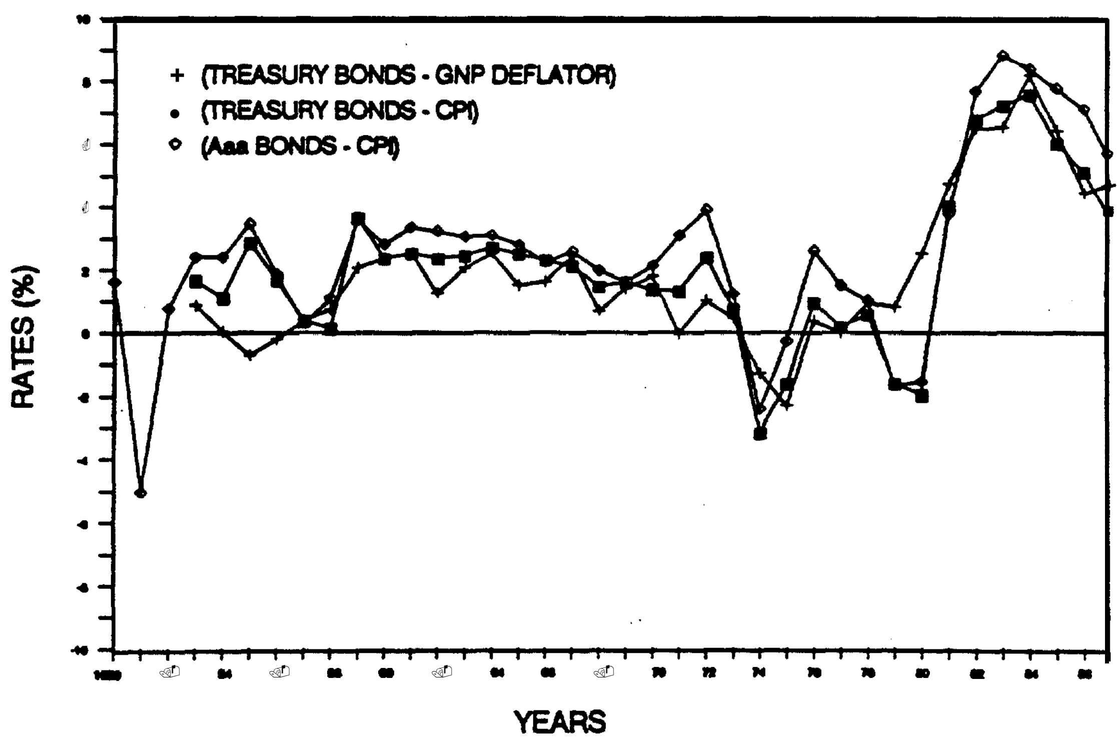

Figure 6. Discount Rates

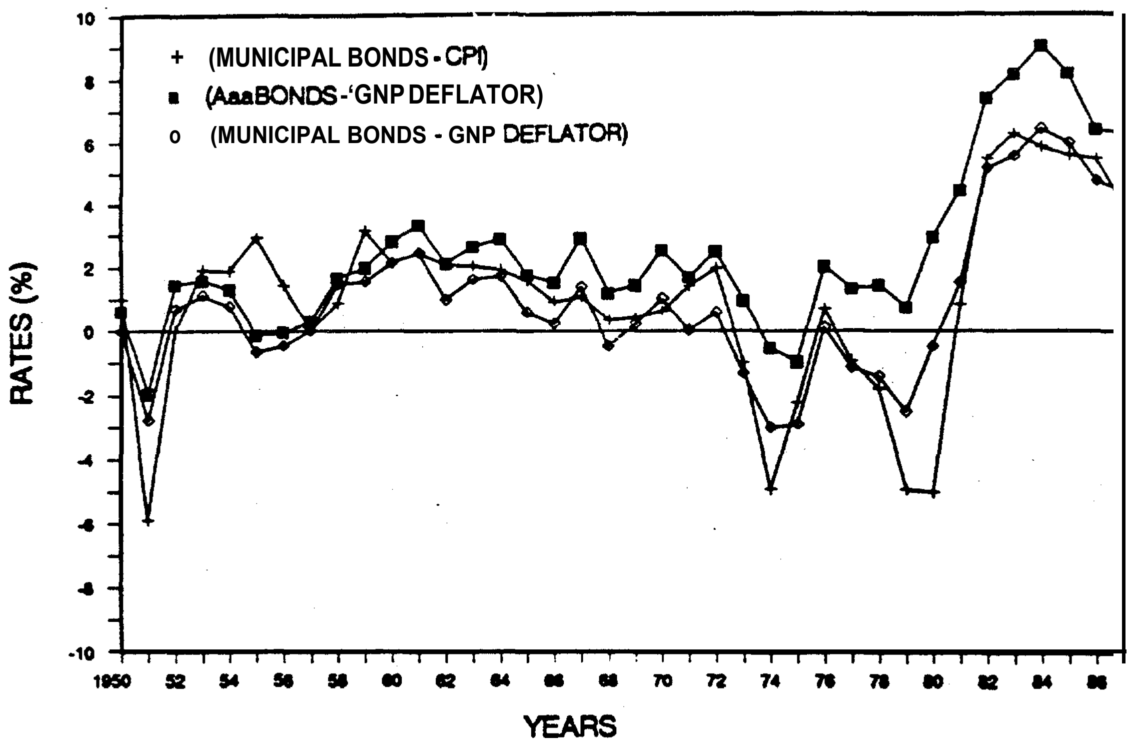

Figure 7. Discount Rates

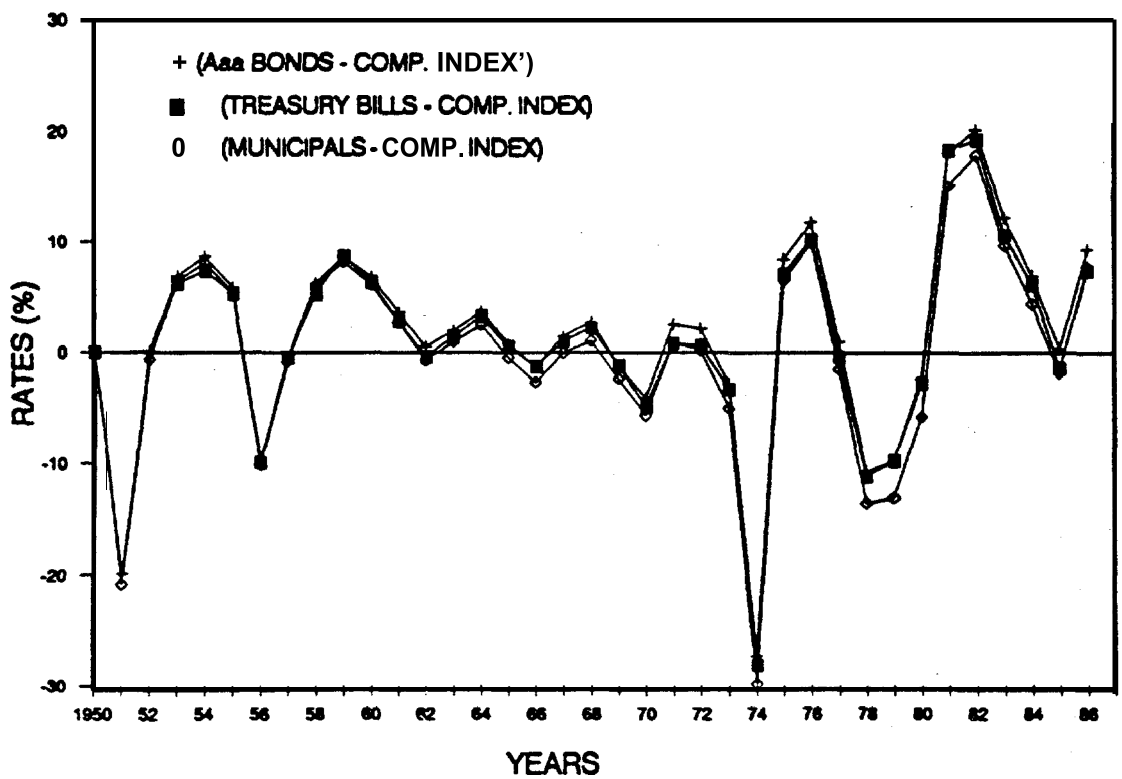

Figure 8. Discount rates

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and end of the decade. During these inflationary surges, the economy was subjected to negative discount rates. During the 1980's, discount rates have been unusually high due to relatively low inflation rates and high interest rates.

The long term trend of relatively low discount rates with higher rates more recently is further shown in Table 3. From 1953 to 1987, the average value for each of the 6 computed discount rates fell in a range from 1.0 percent to 2.8 percent. However, from 1980 to 1987, they ranged between 3.5 percent and 6.6 percent. A frequency distribution for each decade from 1950 to 1987 is shown on Figure 9. These distributions indicate that during most of this period, a low discount rate would be appropriate, on the order of 1 to 2 percent. During, the 1980's, a higher rate of about 6 percent would appear to be appropriate. However, it is important to note that discount rates have generally declined from about 1983-1984. In 1987, the six discount rates fell in a range of 4.0 to 6.4 percent and they averaged 4.9 percent.

Conclusions and Recommendations

The question arises as to what is the appropriate discount rate to use in an economic'analysis of pavements. The following points are offered for use in adopting a particular value:

1. The difference between interest rates and inflation rates does not remain constant over time. Therefore, it is not possible to identify a unique discount rate which will always be correct. As shown on Figures 6 and 7, there were very drastic changes in discount rates during the late 1970's and the early 1980's. It is clear that the selection of an appropriate rate should not be based on unusual economic conditions which may occur for a relatively short period of time.

2. Over the long run, discount rates have been relatively low, on the order of 1 to 2 percent. During the early and mid 1980's, these rates have been in a range of 5 to 6 percent. They have been declining from 1983-1984.

3. Future interest and inflation rates cannot be reliably predicted over a long period of time, such as 30 years. Whether discount rates will return to their long term range of 1 to 2 percent or whether they will remain relatively high is unknown. Conditions in the US economy may lead to continued higher discount rates for the near future.

4. Since we cannot accurately forecast discount rates for long periods of time, a conservative approach would be to adopt a value somewhere between the high and the low range. A reasonable value might be in the range of 3 to 5 percent. It is perhaps on this basis that a discount rate of 4 percent is commonly used in pavement life cycle cost analyses. Such a range recognizes that discount rates of 7 or 8 percent have been relatively rare in this country and have lasted for only a short period of time. Additionally, we have had high discount rates for almost a decade. It is probably unrealistic to assume that they will return in the short run to a range of 1 to 2 percent.

5. Once a discount rate has been selected, Agencies may wish to conduct a

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YEAR	TREASURIES MINUS CPI	TREASURIES MINUS GNP DEFLATOR	Aaa BONDS MINUS CPI	Aaa BONDS MINUS GNP DEFLATOR	MUNICIPALS MINUS CPI	MUNICIPALS; MINUS GNP DEFLATOR
1950			1.6	0.6	1.0	0.0
51			-5.0	-1.9	-5.9	-2.8
52			0.8	1.5	0.0	0.7
53	1.7	0.9	2.4	1.6	1.9	1.1
54	1.1	0.0	2.4	1.3	1.9	0.8
55	2.9	-0.7	3.5	-0.1	2.9	-0.7
56	1.7	-0.2	1.9	0.0	1.4	-0.5
57	0.4	0.4	0.3	0.3	0.0	0.0
58	0.1	0.7	1.1	1.7	0.9	1.5
59	3.7	2.1	3.6	2.0	3.2	1.6
60	2.4	2.4	2.8	2.8	2.1	2.1
61	2.5	2.5	3.4	3.4	2.5	2.5
62	2.4	1.3	3.2	2.1	2.1	1.0
63	2.5	2.1	3.1	2.7	2.0	1.6
64	2.7	2.5	3.1	2.9	1.9	1.7
65	2.5	1.5	2.8	1.8	1.6	0.6
66	2.3	1.6	2.2	1.5	0.9	0.2
67	2.1	2.4	2.6	2.9	1.1	1.4
68	1.5	0.7	2.0	1.2	0.3	-0.5
69	1.6	1.4	1.6	1.4	0.4	0.2
70	1.4	1.8	2.1	2.5	0.6	1.0
71	1.4	0.0	3.1	1.7	1.4	0.0
72	2.4	1.0	3.9	2.5	2.0	0.6
73	0.8	0.5	1.2	0.9	-1.0	-1.3
74	-3.2	-1.3	-2.4	-0.5	-4.9	-3.0
75	-1.6	-2.3	-0.3	-1.0	-2.2	-2.9
76	1.0	0.4	2.6	2.0	0.7	0.1
77	0.2	0.0	1.5	1.3	-0.9	-1.1
78	0.6	1.0	1.0	1.4	-1:s	-1.4
79	-1.6	0.8	-1.7	0.7	-4.9	-2.5
		2.6		2.9		
80	-4.0	4.7	-1.6	4.5	-5.0 0.8	-0.5
81	6.8	6.5	3.8	7.4	5.5	1.5
82			7.7	8.1	6.3	5.2
83			8.8			
84	6:0 3-i	X:X	8.4	9.0	5.9	5.6
85	)	6.4	7.8	8.2	5.6	6.5 6:0
86	5.2	4.5	7.1	6.4	5.5	4.8
87	4.0	4.7	5.7	6.4	4.0	4.7
		1.8	2.8	2.6	1.2	1.0
1953-87	1.6	0.4	2.2	1.0	1.7	0.5
		1.8	[illegible]	[illegible]	1.5	1.1
1960-69 / 1970-79	2.3 / 0.1	0.2	1.1	1.2	-1.1	-1.1
1980-87	5.0	5.6	6.0	6.6	3.5	4.1

Table 3. Discount Rates

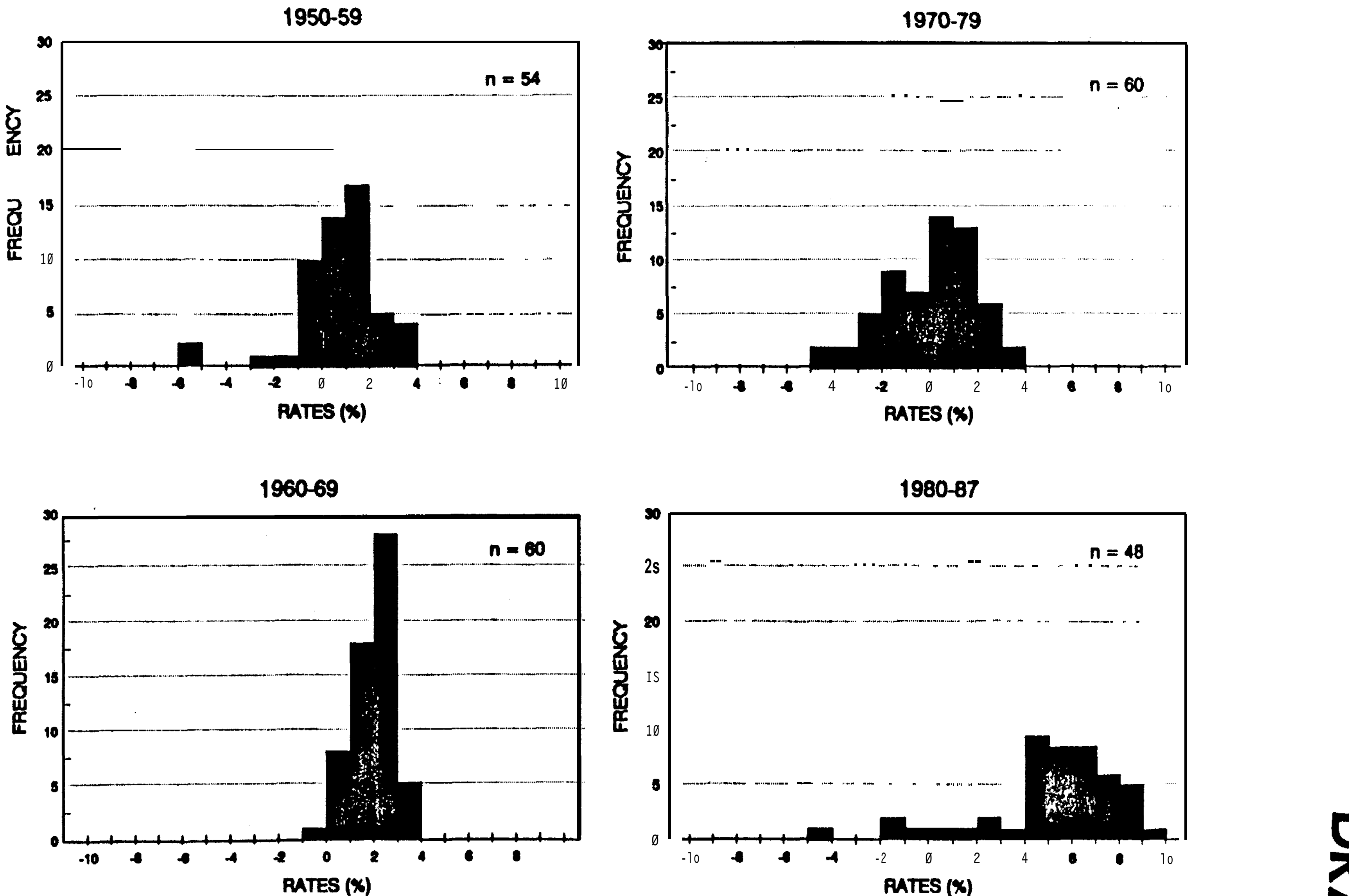

Figure 9. Frequency Distributions for Six Discount Rates by Decade

sensitivity analysis by calculating Present Worths or Equivalent Uniform Annualized Costs using several discount rates. It gives an indication as to how sensitive the outcome of the analysis is to the discount rate. If one alternative is favored over a range of discount rates, the agency can have confidence that the analysis has truly identified the least cost alternative. It is important however to emphasize, that the sensitivity analysis should not be used-for changing discount rates on a project by project basis. However, they can help in the selection of the particular alternative that will be built.

Memorandum

U.S. Department of Transportation

Federal Highway Administration

Washinoton, D.C. 20590

Subject: Resilient Modulus Testing Equipment

Date: [illegible] 24 19[illegible]

From: Chief, Pavement Division

Reply to Attn of: HHO-12

To: Regional Federal Highway Administrators

Attached is a summary of responses to our November 16, 1987, memorandum on the above subject. A listing of manufacturers of resilient modulus testing equipment used or proposed for use by State highway agencies (SHA's) is included as an attachment to the summary. There are currently 24 SHA's that are or soon will be performing laboratory resilient modulus testing on unbound and/or bound material. Most SHA's are using laboratory resilient modulus for research purposes only. The equipment used and the cost of that equipment is quite variable as can be seen in the attached summary.

As you are aware, the definitive material property used to characterize roadbed soil and to assign layer coefficients (flexible pavements) for pavement design in the "AASHTO Guide for Design of Pavement Structures" (1986 Guide) is the resilient modulus.

The 1986 Guide recommends that low stiffness materials, such as natural soils, unbound granular layers and even stabilized layers and asphalt concrete be tested using resilient modulus test method AASHTO T274. Although the testing apparatus for each of these types of materials is basically the same, there are some differences, such as the need for triaxial confinement for unbound materials.

The 1986 Guide also states that the bound or higher stiffness material such as stabilized bases and asphalt concrete may be tested using the repeated-load indirect tensile test (ASTM D4123). Appendix F to the 1986 Guide notes that ASTM D4123 provides an estimate of the modulus of asphalt concrete and other relatively low-strength materials under simulated field-loading conditions. The estimate may or may not correlate well with the resilient modulus value obtained using AASHTO T274.

The resilient modulus values can be used directly for the design of flexible pavements, but must be converted to a modulus of subgrade reaction (k value) for design of rigid or composite pavements.

Some of the manufacturers equipment listed in the attachment does not include apparatus needed for triaxial confinement of a specimen. Many States modify standard test procedures for reasons of practicality and speed. In order to learn more about the advantages and disadvantages of the currently used resilient modulus testing equipment, we suggest that SHA's call or write the various State contact persons listed in the attached summary as well as the equipment manufacturers.

We are currently working with the State of Washington to produce a videotape using **WSDOT's** resilient modulus testing equipment. The tape will outline the AASHTO and ASTM resilient modulus test procedures. It will also include **WSDOT's** test procedures and explain how and why they deviate from the AASHTO and ASTM test procedures. We anticipate that the tape will be available for distribution later this year.

As noted earlier, the 1986 Guide uses resilient modulus to characterize soil support and to assign asphalt pavement layer coefficients. It further stresses, the need for a more rational approach to incorporate material engineering properties into the asphalt mixture design process. A number of research studies are being conducted by FHWA, NCHRP, **and** SHRP in this area. We will keep you informed as results become available.

We feel that the information included with this memorandum would be helpful to those States contemplating the use of laboratory resilient modulus, as well as those States which are currently doing work in this area. Sufficient copies of this memorandum and attachments have been provided for distribution to the division offices and their appropriate State counterparts.

If you have any questions, please contact Messrs. Tom **Fudaly** at 366-1338 or Dan **Mathis** at 366-1340.

Norman J. Van Ness

SUMMARY OF RESILIENT S EQUIPMENT USAGE BY REGION

REGION 1

State	Primary Use	Brand & Model	Purchase Date	Purchase Amount	State Contact	Telephone Number
* Maine	Research	Hicks & Vincent IB	1987	$38,000	Warren Foster	(207) 289-5668
** New Hampshire	Design (Bound mat'l)	Retsina, Mark VI	1987	$18,000	Phil McIntyre	(603) 271-3151
New York	Design	SBEL Co.	1980	$22,000	David Suits	(518) 457-4704

* Maine will soon be performing laboratory resilient modulus testing for research work and eventually hope to use laboratory results for design.

** New Hampshire will soon be performing laboratory resilient modulus testing on bound material for use in design.

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REGION 3

State	Primary Use	Brand & Model	Purchase Date	Purchase Amount	State Contact	Telephone Number
Maryland	Research (Bound and unbound mat'l)	MTS, 410, 413, 414, 422, 464	1983	$100,000	Michael Arastek	(301) 321-3560
Pennsylvania	Research and Design (Bound mat'l)	Retsina, Mark IV	1981	$10,600	Prithus Kandhal	(717) 787-5229
Virginia	Research (Bound mat'l)	Retsina, Mark II	1980	$5,000	Bill Maupin	(804) 293-1948
West Virginia	Research and Design	MTS (see attachment 1)			Berke Thompson	(304) 348-3664

The Virginia Research Council performs the research work for the Virginia DOT. They are in the process of obtainina a Retsina Model Mark VI for approximately $15,000.

REGION 4

State	Primary Use	Brand & Model	Material Tested	Purchase Date	Purchase Amount	State Contact	Telephone Number
Florida	Research	MTS, 312.31 MTS, 312.21 (see attachment 2)	Asphaltic Concrete Soils	1975 1975	$50,000 $48,000	Larry Smith or Gale Page	(904) 372-5304
Georgia	Research	(See attachment 3)	Bound	1975 & 1986	$10,000	William Webb	(404) 363-7546
* Kentucky	Research	Structural Behavior Engr. Lab.(SBEL) STD-1000	Bound and Unbound	1974	$5,200	David Allen, University of Kentucky	(606) 257-4513
Miss.	Research	Retsina, Mark IV	Asphaltic Concrete	1980	$10,000	Joe Scheffield	(601) 359-1174

* Kentucky Transportation Cabinet to purchase custom-made model from Materials Testing System (MTS) Minneapolis, MN, for $119,000 by June 1988.

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State	Primary Use	Brand & Model	Purchase Date	Purchase Amount	State Contact	Telephone Number
Illinois	Research	(Built their own device)		--------	Jake Dhamrait	(217) 782-7206
Michigan	Research (Bound mat'l)	MTS	--w-m-	-------	Jack DeFoe	(517) 322-5711
Minnesota	Research	MTS 810	1980	$99,500	George Cochran or Neil Magee or Dave Rattner	(612) 296-7134 (612) 296-7848 (612) 296-9740

<u>REGION 6</u>

2.6.5

State	Primary Use	Brand & Model	Purchase Date	Purchase Amount	State Contact-	Telephone Number
* Texas	Research (Bound mat'l)	Retsina Mark IV	1975	s---w--	Paul Krugler	(512) 465-7603
New Mexico	Research (Bound and unbound mat'l)	Custom made by University of Oregon	1982	$45,000	John Tenison	(505) 827-5565

* The Bituminous concrete section of DHT Materials and Test Division (D-9) occasionally does resilient modulus testing. It is not done routinely and done only when additional information about a mix is needed.

REGION 7

State	Primary Use	Brand & Model	Purchase Date-	Purchase Amount	State Contact	Telephone Number
* Kansas	Research and Design	Cox and Sons, Inc. C5-4000KA	1984	$57,000 plus $30,000 accessories	Glenn Fager	(913) 296-741Ø

An additional resilient modulus testing machine has been purchased by KDOT and will be received in early 1988. This unit was manufactured by Research Engineering and is a component type system. The load frame is Model RE-CLF-5ØØØ and the Air Electric Loader is Model No. RE-CL-82. This unit is operated through an IBM PC-AT processor. The cost of this unit is $36,000.00 with up to an additional $5,000.00 in accessories. When this unit is brought on line at KDOT, it will be used primarily for the design of pavement structures. The contact person at KDOT for this unit is Mr. Jeff Frantzen. His telephone number is (913) 296-3ØØ8.

REGION 8

State	Primary Use	Brand & Model	Purchase Date	Purchase Amount	State Contact	Telephone Number
Colorado	Research	Retsina Mark III	1974	$6,ØØØ	Lex O'Connor or Dick Hines	(3Ø3) 757-9449 (3Ø3) 757-9724
Utah	Design	MTS	1972	s---w--	Wade Betenson	(8Ø1) 965-43Ø3

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State	Primary Use	Brand & Model	Purchase Date	Purchase Amount	State Contact	Telephone Number
California	Research	Retsina, Mark II	1974	$5,600	Robert Doty	(916) 739-2361

Nevada - Will soon purchase a device by "Research Engineering" for research purposes. The State Contact will be Pat **Schoener** or Ted **Beeston** (702) 885-5875.

REGION 10

State	Primary Use	Brand & Model	Purchase Date	Purchase Amount	State Contact	Telephone Number
Alaska'	Research	Hicks and Vincent	1987	$45,600	Eric Johnson	(907) 338-2121
Washington	Research & Design	Hicks and Vincent IA	1983	$29,000	Newton Jackson	(206) 753-7110
* Oregon	Research	Retsina Mark IV	1980	---de--	Dick Dominick	(503) 388-2621

* Oregon has recently ordered equipment manufactured by "Research Engineering" at a cost of $33,600.

West Virginia DOH Resilient Modulus Equipment List

Equipment Manufacturer and Type	Model Number	Date Purchased	cost
MTS Inc. Material Test System	810 Series	Dec. 1971	$63,923
MTS Inc. 22 Kip Load Frame	Not Available	Late 1983	$3,500 estimated
Schaevitz Engineering Co. Linear Variable Differential Transformer	100MHR Range +/- 0.100 inch	May 1982	$250
Research. Engineering Co LVDT Clamps (2 each)	RE-PRC	May 1982	$305 each
Wavetech Inc. Function Generator	186	Not Known	$350
Air Compressor	(Air compressor set up for entire lab is used)		
Blue M. Inc. Construction Temperature Oven	OV490-I	May 1963	$330
Hobart Manufacturing Co. Mixer	C-1[illegible]-T	Oct. 1970	$495
Hewlett Packard Co. Oscilloscope	1702A	Late 1974	$6,000
Research Engineering Co. Triaxial Chamber	RE-SA-150	May 1982	$2,920
Mettler Co. Balance	P11N	Dec. 1977	$1,940
Soiltest Inc. Membrane Expander	No number	May 1982	$85
Soiltest Inc. Membranes	T-614	Purchased as needed	$60/doz.

Florida DOT Resilient Modulus Equipment List

System No. 1 - Asphalt Test System

Consists of the following:

1. Load frame - 55 Kip (M.T.S.), Model No. 312.31

2. Activator - 22 Kip (M.T.S.), Model No. 204.63

3. Hydraulic service manifold - (Series 284) (M.T.S.), Series 284

4. Load Cell 10 metric ton - (M.T.S.) - Asphalt, Model No. 661.21A-03

5. Load Cell 1500 D.G.F - (M.T.S.) - Model No. 661.13A-05

6. Temperature control chamber - (Thermotron Corp.), Model No F-3-Ch-Co2

7. Split Tension Load Frame - (Custom Made)

8. Electronic Console (M.T.S.)

   A. 409 Temp. Control panel
   B. 430 digital indicator panel
   C. 417 counter panel
   D. 410 digital function generator
   E. 442 controller arranged with following modules:
      (a) Serve Control - Model 440.13
      (b) Valve Driver - Model 440.14A
      (c) Feed Back selector - Model 440.31
      (d) Limit detector - 440.41
      (e) A.C. conditioner - Model 440.22
      (f) D.C. conditioner - Model 440.21
   F. 410 pulse sequence panel
   G. 413 Master control panel

9. Gould Brush Recorder - Model -1111-1707-120, consists of the following modules:

   A. D.C. Amplifiers - Model 13-4215-32 (2 each)
   B. Transducer - Model 13-4218-00
   C. Carrier Amplifier - Model 13-4212-02

   Date of Purchase - 1975
   cost - $50,000

Equipment List

System No. 2 - Soils Test System

Consists of the following:

1. Load frame - 22 Kip (M.T.S.), Model No. 312.21

2. Actuator - 3.3 Kip (M.T.S.), Model No. 204.51

3. Hydraulic service manifold (series 284) (M.T.S.), Series 284

4. Load cell - 500 K.G.F. (M.T.S.) (w/protector), Model No. 3170

5. Triaxile chamber - (Wykeham-Farrance Eng.), Model No. 11006

6. Electronic console (M.T.S.)

   A. 417 counter panel
   B. 410 digital function generator
   C. 442 CONTROLLER - (arrangement is same as system No. 1)
   D. 410 pluse sequence panel
   E. 413 Master Control panel

7. Gould Brush Recorder - arrangement same as system no. 1
   - Model No. -1111-1707-120

   Date of Purchase - 1975

Cost - $48,000

Hydraulic Power Supply **(MTS)**

3000 psi capacity
21 gpm
Model No. 510.218

Date of Purchase - 1985
cost - $14,300
Note: This Hydraulic Power Supply is capable of supplying both the Asphalt and Soil Test systems with 3000 psi

GEORGIA DOT RESILIENT MODULUS EQUIPMENT LIST

Part	Manufacturer
2 Triaxial Cells	Soiltest
1 Load Frame for 2 Samples	GA DOT - Office of Materials and Research Machine shop
1 Strip Recorder (Brush 2 Channel)	Gould Instruments
4 Pressure Regulators (Model #40-100)	Moore Products Company
4 Pressure Gauges	
4 LVDT's (Transducers Model #SS-203)	G. L. Collins
2 Belloframs (Size 4)	Bellofratn Products Company
2 Mufflers	
2 Recycling Timers (Model #CX400)	Eagle Signal Controls
4 Revolution Counters	
2 24 Volt Power Supplies	GA DOT - Research
Miscellaneous Plumbing and Electrical Materials	

Resilient Modulus Equipment Manufacturers

The following is an alphabetical listing of manufacturers of resilient modulus testing equipment that is currently used or proposed for use by the SHA's:

Cox and Sons, Inc.
P.O. Box 674
Colfax, California 95713
Phone: (916) 346-8322

Hicks & Vincent (H&V)
Material R and D
3187 NW Seneca Place
Corvallis, Oregon 97330
Phone: (503) 757-1293

Material Testing System (MTS)
P.O. Box 24012
Minneapolis, Minnesota 55424
Phone: (612) 937-4000

Research Engineering
2640 Dundee Road
San Pablo, California 94806
Phone: (415) 223-4798

Retsina Company
601 Brush Street
Oakland, California 94607
Phone: (415) 268-0821

Structural Behavior Engineering Laboratories, Inc. (SBEL)
P.O. Box 23167
Phoenix, Arizona 85063
Phone: (602) 272-0274

LONGITUDINAL JOINT CONSTRUCTION AND EDGE DROP-OFFS

STATE-OF-THE-PRACTICE

by

Steve A. Call

Highway Engineer Trainee

FHWA

Pavement Division

March 1989

INTRODUCTION

In January of 1987 a questionnaire dealing with longitudinal joint construction with asphalt pavements was sent out to all State highway agencies by the Transportation Research Board Committee on Flexible Pavement Construction. Forty-five agencies responded to the survey. The questionnaire asked if step-offs (drop-offs) were routinely permitted overnight or longer, before placement of the adjacent mat, on either new construction or on resurfacing projects. Questions followed concerning conditions under which drop-offs were allowed, joint construction techniques, and alternate procedures used. A compilation of the responses to the questionnaire was made in May of 1988 by C.S. Hughes. It included his conclusions and recommendations (see appendix).

Since this questionnaire was sent out there has been much interest and activity in the area of longitudinal joint construction. In addition, many State highway agencies have been encouraged to, and are trying to, develop pavement edge drop-off policies. This paper is an attempt to update and add to the information gathered in the 1987 survey, in order to provide a "state-of-the-practice" report.

As was indicated by tne results of the 1987 survey, longitudinal joint construction practices vary from State to State. It is not the intent of this paper to evaluate the various construction practices of the States, but rather to provide information on what different States and regions are doing to mitigate the hazards created by edge drop-offs. To set the stage for this information, a literature review is given detailing the results of the most recent studies concerning the safety aspects of drop-offs.

LITERATURE REVIEW OF SAFETY RELATED ASPECTS OF PAVEMENT EDGE DROP-OFFS

An edge drop-off occurs when there is a vertical difference in height between adjacent road surfaces. Drop-offs may occur as a result of paving or resurfacing operations, or milling or other types of excavation work. They also may occur as the result of the deterioration of an adjacent surface. The hazard results when a driver of a vehicle crosses over the drop-off, dropping his wheel(s) down onto the lower surface, and then tries to steer back up onto the higher surface. An overcorrection may result in loss of vehicle control, while a gradual correction may result in the phenomena known as "scrubbing." Scrubbing occurs when the steering angle is insufficient to overcome the opposing force of the face of the drop-off, hence, "scrubbing" of the side of the tire occurs along the drop-off face. Once sufficient steering angle is imparted, the wheels mount the pavement edge and, in the absence of an opposing force, the vehicle has a sudden change of direction, often times causing lane exceedance or loss of control. As the height of the drop-off increases, so does the severity of the situation. For this reason engineers have tried to determine the height of drop-offs at which mitigating action needs to be initiated.

Current literature cites four major studies that have been conducted by various agencies since 1976 pertaining to vehicle responses to an edge climb maneuver. These studies, in chronological order, are:

The Effect of Longitudinal Edge of Paved Surface Drop-off on Vehicle Stability, E. Nordlin, D. Parks, R. Stoughton, and J. Stoker, California Department of Transportation, 1976.

Vehicle Controllability in a Pavement/Shoulder Edge Climb Maneuver, R. Klein, W. Johnson, and H. Szostak, Society of Automobile Engineers Technical Paper Series, 1978.

Pavement Edges and Vehicle Stability- A Basis For Maintenance Guidelines, Don Ivey and Richard Zimmer, Texas Transportation Institute, 1982.

Pavement Edge Drop, Paul Olson, Richard Zimmer, and Val Pezoldt, University of Michigan Transportation Research Institute, 1986.

This paper will summarize both the test procedures and the findings of these four studies. It is important. to note that testing procedures differed in the four studies because each of the studies had different goals. As the pool of knowledge grew, the procedures also evolved somewhat. It is recognized now that when a vehicle drives over a drop-off, through inattention, recovery from a scrubbing condition is the most difficult form of recovery and therefore should ultimately be the determining factor in the conclusions.

In Nordlin's study 50 tests were conducted using professional drivers in four different vehicle types: small, medium, and large passenger cars, and a full-sized pickup truck. Three different drop-off heights were used- 1.5, 3.5, and 4.5 inches. Vehicles were driven from an A.C. shoulder onto either an A.C. or soil surface, and returned to the A.C. shoulder at speeds of 60 mph and at angles of less than 10 degrees. In these tests either two or four wheels were dropped off the shoulder and then returned. This study did not examine the pavement edge scrubbing condition and used only vertical drop-offs. In addition the combined width of the lane and shoulder was 17 feet, allowing more room for recovery.

Nordlin found that although experiencing a "significant jolt and accompanying front end noises" at the larger drop-off heights, there was no real problem with vehicle stability, no deviation in vehicle trajectory, and no encroachment into adjacent lanes. Less than one wheel revolution was required for the first wheel to mount the various drop-off heights.

In Klein's study three different size passenger cars were used in closed loop tests. The car's two right wheels were gradually dropped 4.5 inches onto an earth shoulder. Pylons were used to keep the wheels close to the pavement edge increasing the chance for scrubbing. Klein tested only vertical edge drops in his study. The drivers were told to drive at constant speeds, increasing from 25 to 55 mph in 5 mph increments on successive runs. Twenty-two naive (non-professional) subjects were used on 73 runs. On 34 runs the tires did not scrub, but on the other 39 they did. On the non-scrubbing runs there were no lane exceedances, but over half (22 of 39) of the scrubbing runs resulted in lane exceedances. Klein found that a correlation existed between vehicle speed and lane exceedance. Each vehicle had a critical speed at which recovery from shoulder climbs became difficult (83% failure). In the two smaller cars the critical speeds were 30 and 32 mph. In the larger car the critical speed was 42 mph.

In the open looped test Klein used four test vehicles and drop-off heights ranging from 2 to 4.5 inches. Once again the most hazardous results occurred during scrubbing. Whether or not a vehicle was able to climb a drop-off was a function of closing velocity. On a graph of closing velocity (the component of velocity perpendicular to the pavement edge) verses drop-off height, it was shown that, at a height of about 4 inches, closing velocity needed to climb the pavement edge increased sharply. For this reason 4 inches was suggested as a maximum drop-off height. Five inches was determined to be the maximum height that could be climbed due to the undercarriage characteristics of vehicles and side forces on the wheel.

Don Ivey's study built upon the preceding two studies by Nordlin and Klein. He used drop-off heights of 1.5, 3, and 4.S inches with various edge shapes including a 45 degree taper and a vertical edge. He used, as previously, three passenger cars and a pickup for test vehicles. Different types of drivers were used ranging from professional to naive, however only the professional driver drove the complete matrix of tests. Test speeds of 35, 45, 55 mph were driven with three different vehicle positions: scrubbing, two wheels off the pavement, and four wheels off the pavement. Ivey used a subjective rating system which had the driver rate the difficulty of the edge climb maneuver, however only the professional driver was used to rate the various climbing maneuvers since he was the only one to drive the complete matrix of tests.

Ivey found that the professional driver handled all the variations easily except for the 4.5 inch edge drop, on the vertical edge, in the scrubbing condition. It was therefore concluded that the 4.5 inch edge drop was unsafe at speeds as low as 35 mph. The 45 degree angle was safe, even at a 6-inch drop, at speeds up to 55 mph. Velocity, drop-off shape, and proximity to the edge were the factors with the greatest influence on safety.

Paul Olson's study used most of the same variables that the former studies used (i.e. vehicle type, velocity, edge shape, shoulder type, and edge drop heights). His investigation, however, was "primarily concerned with evaluating the performance of ordinary (naive) drivers on their first encounter with the edge drop". He also examined "subject learning" and found that its effects were minimal. The criteria he used to determine the safety of each maneuver was lane exceedance beyond a 12.5-foot lane with the drop at the edge of the lane.

Olson found that 4.5-inch vertical drops could not be negotiated by the naive subjects safely at speeds as low as 20 mph. The 3 inch vertical drop could be negotiated at speeds of between 20 and 25 mph in smaller cars and 30 mph in the largest passenger car. No safe maximum height was defined for speeds greater than 25 mph. Using the 45 degree bevel edge, virtually all runs at heights up to 4.5 inches were made without intruding beyond the lane adjacent to the edge drop at speeds up to 55 mph. The beveled edge was a suggested treatment at higher speeds. Finally, he concluded that height, not shoulder material, was the controlling factor, and that small cars had more difficulty than large cars. The results of Olson's study suggest that the recommendations of other studies are not adequate for high speed facilities, if the determining factor is recovering from a scrubbing condition. Maximum vertical heights of edge drops on these facilities should be less than 3 inches, although how much less has not been determined. Future studies should address this issue.

PAVEMENT EDGE DROP-OFF POLICY- STATE OF THE PRACTICE

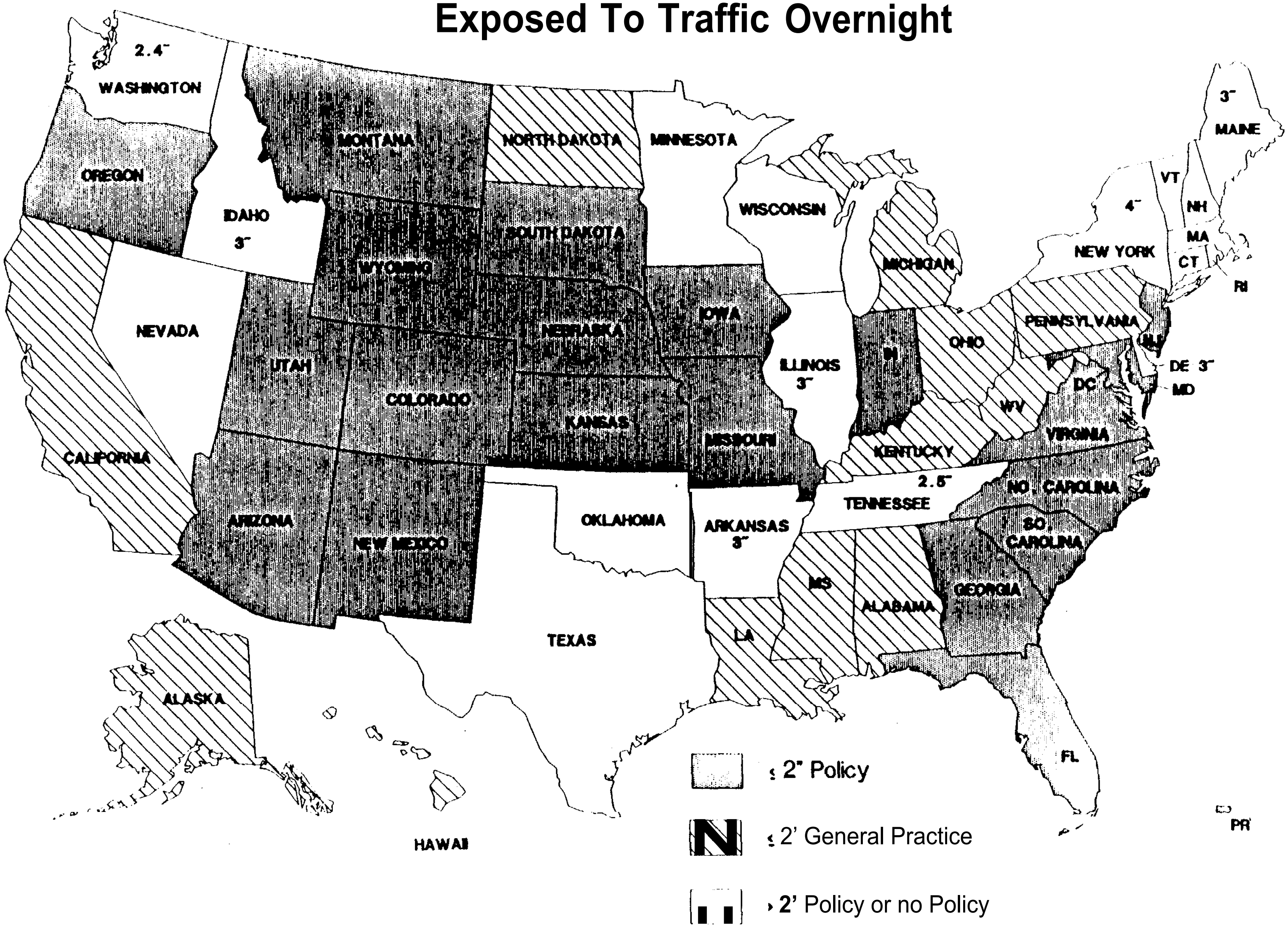
In the memorandum issued December 1, 1986, from the FHWA Construction and Maintenance Division, it states that drop-offs "greater than 2 inches, left overnight, and immediately adjacent to traffic, have high accident potential." The C&M Division recommended corrective action or a combination of actions for drop-offs greater than 2 inches (see appendix). The memorandum "strongly encouraged" the regions to work with the states in developing pavement drop-off policies.

The following figure illustrates the "state-of-the-practice" in the United States in regards to the 2-inch drop-off level. The figure divides the States into three groups. The first group consists of those States that have formal drop-off policies that allow a Z-inch or less maximum drop-off in work zones exposed to traffic overnight or require a taper for drop-offs exceeding 2 inches. The second group consists of those States that have not formulated a formal policy, but their general practice meets the requirements of the first group. The third group consists of those States that have a policy allowing greater than 2 inches, or have no policy at all.

This information was obtained from surveys conducted by TRB and various regions, and supplemented by information obtained from telephone conversations with regional and division personnel. It is noteworthy that in some cases where there was more than one source available, there was a lack of agreement as to policy or practice. In these cases, preference was given to sources citing State Specifications or Codes.

A more detailed summary of each State's position concerning drop-offs follows. The States are organized according to FHWA regions so as to show patterns on a regional basis. While the information is not detailed, in some cases, each State is represented and the summary takes advantage of as many sources as possible, given the time constraints imposed.

Maximum Vertical Drop Off Exposed To Traffic Overnight



2.7.7

REGION 1

With a few exceptions, the States in Region 1 do not have formal pavement drop-off policies.

In the State of Connecticut edge drop-offs are not considered to be a problem. For the most part traffic is kept off the joint area, using the rest of the roadway. With multiple lifts, the pavement in adjacent lanes is matched before beginning the next lift.

The State of Maine uses channelizing devices spaced every 50 feet when the drop-off exceeds 3 inches in vertical height. On a resurfacing project creating drop-offs of less than 3 inches, channelizing devices are placed 2 feet outside of the edge of the pavement at 600 foot intervals with the MUTCD, W8-9 "low shoulder" signs every 1/2 mile. When the drop-off is greater than 3 inches, 4 feet of shoulder material is required to be placed with channelizing devices placed as stated before. The speed limit on such projects is set at 45 mph.

Massachusetts has elected not to adopt a drop-off policy because "in some instances such a policy would create more problems than it would solve." Instead it was decided that each traffic control plan should place special attention to drop-offs in work areas and individual needs should be carefully evaluated.

The State of New Hampshire has no specific height requirements, but specifications state that open excavations shall not be exposed overnight, on weekends, or on holidays. No guidelines for resurfacing projects were given, but the State feels that they have few drop-off situations because of their specifications, and attention given by project personnel.

New Jersey has the strictest policy in the Region, requiring a gravel wedge at a slope of 6:1 when adjacent excavation is greater than 2 inches. On resurfacing, adjacent lanes of pavement are matched every 1500 feet. Lift thicknesses are 2 inches. They also use a longitudinal wedge joint design. Appropriate signing and a double yellow line is required on their resurfacing projects to keep traffic off the joint.

The State of New York has not adopted a formal drop-off policy. The State relies on a section in its Standard Specifications. It was requested that NYSDOT develop a special specification dealing with drop-offs. This issue is still unresolved at this time.

Rhode Island has not developed a formal policy because they did not feel that drop-offs were a problem. It is general practice, with drop-offs greater than 4 inches, to require either a 4:1 transition slope or a median barrier.

Vermont does not have a specific policy on drop-offs, but does require the pavement to be matched in adjacent lanes by the end of the day. This issue was to be discussed prior to the start of the 1988 construction season.

In Puerto Rico the standard specifications state that pavement-repairs and construction on both bituminous and PCC pavements will be initiated and completed during the same working day. This eliminates unnecessary drop-offs along and adjacent to travel lanes. Where isolated or continous excavation is expected as part of the construction project, appropriate channellizing devices are specified. No height specification for drop-off are given.

(The information for this summary was obtained from a survey conducted by TRB and a survey taken by FHWA Region 1.)

REGION 3

The State of Delaware has no height specifications for drop-offs on milling type projects, however, they said that drop-offs of 3 or more inches do occur. On resurfacing projects, drop-offs of 1 inch or more require signing. Drop-offs of between 2 to 6 inches require cones or vertical panels and are tolerated for the length of one days paving operation. Drop-offs of greater than 6 inches require concrete barriers when within 10 feet of the traveled way and require barricades when outside of 10 feet.

Maryland requires pavement in adjacent lanes to be matched by the end of the working day when vertical drop-offs exceed 2 inches. When drop-offs are less than 2 inches pavement must be matched within 24 hours. Reduced speed limits are enforced within construction work zones. They said that nothing was mentioned in their specifications for excavation work.

In Pennsylvania longitudinal edge drop-offs are generally limited to 25 feet in length at the end of each days work, and a maximum of 2 inches in height. This does vary from district to district.

Virginia requires that pavement having drop-offs greater than 2 inches, have lanes of adjacent pavement matching by the end of a days operation. Appropriate signing is required when drop-offs occur.

West Virginia generally sets 2 inches as the maximum drop-off allowed although it has no formal policy. They generally do not prevent traffic from crossing the longitudinal joint.

(The information for this summary was obtained from a questionnaire sent out by TRB and from specifications from the States of Virginia and West Virginia.)

REGION 4

Although not all the States in Region 4 have adopted a formal policy mitigating pavement drop-offs, they, at least in general practice, have strict limits.

Alabama generally does not permit drop-offs of more than 2 inches to exist overnight. If they occur a temporary 1:1 longitudinal taper joint is required and is later removed when paving resumes.

Florida sets a maximum height of 1.5 inches for drop-offs that traffic is expected to cross. This may be increased to 2 inches for low speed situations. Where traffic is not expected to cross, less than 2 inch drop-offs require warning signs only. Drop-offs between 2 to 4 inches require drums, panels, or barricades. With drop-offs greater than 4 inches either positive separation or a 3:1 wedge is required. For temporary conditions, drop-offs greater'than 4 inches may be protected by drums, panels, or barricades for short distances, during daylight, while work is being performed.

The State of **Georgia** requires pavement on the Interstate system to be matched in adjacent lanes by the end of the next day. They set 2 inches as the maximum height allowable for drop-offs exposed to traffic. They also require appropriate signing where drop-offs occur.

Although **Kentucky** does not have a formal policy concerning drop-offs, they said that projects with drop-offs are generally closed to traffic.

Mississippi generally allows drop-offs of up to 2 inches without protective devices and requires. protective devices at drop-offs greater than 2 inches.

North Carolina has set 2 inches as the maximum drop-off height allowed. All paving projects in the State must have adjacent lanes of pavement matched within 24 hours. Use of the W8-9a sign is required when traffic is exposed to drop-offs.

South Carolina sets 1.5 inches as the maximum drop-off height they will allow on resurfacing projects. They also require warning signs.

Tennessee does not allow night traffic on projects where drop-offs occur. Pavement must be matched in adjacent lanes within 24 hours. Warning lights and barrels are required when the drop-off exceeds 2.5 inches.

(Information for this summary was obtained from a survey conducted by TRB and information provided by Region 4.)

REGION 5

A survey of the States in Region 5 was conducted in 1987 and was confirmed by telephone conversation in February of 1989.

Standard Specifications in Illinois require that drop-offs of 3 or more inches at the edge of the pavement be protected by type I or II barricades at 100-foot intervals when they were greater than 4 miles in length. This applies to both resurfacing and excavation and milling type projects. The pavement in adjacent lanes is required to be matched before the next lift is placed, and within 24 hours. Appropriate signing is required and no open trenches greater than 3 inches are allowed to exist overnight.

Indiana requires, on resurfacing projects only, that barricades be placed where drop-offs exceed 2 inches adjacent to the pavement. Up to 3-inch drop-offs are permitted outside the shoulder. These specifications are contained in the Contract Special Provisions. All other situations are covered in the Traffic Control Plan. Deep excavations at the edge of the pavement require temporary concrete barriers to separate them from the traveled way.

The State of Michigan does not have a formal policy, but has specifications that state that low shoulders be delineated and that hazards be removed as soon as possible. Pavement in adjacent lanes must be matched by the end of the day or else warning signs must be provided and barricades placed every 100 feet to delineate the traveled way. They frequently make use of a longitudinal taper joint when drop-offs are expected to be under traffic.

The State of Minnesota, likewise, does not have a formal pavement drop-off policy, but as a general practice allows drop-offs under 2 inches to be left untreated unless the drop-off occurs between lanes, then warning signs are required. Drop-offs between 2 and 4-6 inches (varies between districts) are signed as low shoulders and may be delineated with channelizing devices. Drop-offs over 4-6 inches are signed and delineated with channelizing devices. In most cases adjacent lanes of pavement must be matching by the end of the day. Excessive drop-offs require the use of concrete barriers.

Ohio has no official drop-off policy, however, drop-offs are considered and discussed during the development of the traffic control plan. Their specifications allow for a maximum 2-inch drop-off and require pavement in adjacent lanes to be matched within 24 hours after placement. Open trenches are protected by barrels. Ohio has utilized, on many occasions, all the techniques discussed in the 1985 memo from the C&M Division.

The State of Wisconsin does not have a drop-off policy, but as a general rule, uses the provisions in the MUTCD. These are included in the contract plan.

(The information in this summary was obtained from surveys conducted by TRB and Region 5.)

REGION 6

The States in Region 6 follow no definite pattern when it comes to mitigating drop-offs in work zones.

The State of **Arkansas** allows a maximum drop-off of 3 inches on the centerline pavement edge and 4 inches maximum at the edge of the shoulder. When resurfacing lifts are less than 1 inch *no* treatment is necessary. Between 1 and 3 inches, at the centerline, an uneven lane sign (WSP-1) is required. At the shoulder edge, a drop-off of between 1 and 4 inches requires that a drop-off sign (WSP-2) be used. Adjacent lanes must be matched within 24 hours unless an emergency arises.

Although there is no formal policy in **Louisiana,** as a general rule, drop-offs of less than 2 inches are allowed to exist without any treatments while drop-offs of greater than 2 inches require matching lanes-of pavement by the end of the day. They are currently looking at a policy patterned after one being developed by the State of Oklahoma.

The State of New Mexico requires a 6:1 taper on the edges of lifts greater than 1.5 inches in vertical height. At heights greater than 3 inches they require panels or barrels in addition to the taper. Adjacent lanes of pavement are usually matched within 24 hours.

Oklahoma, at present, has no drop-off policy in construction work zones. The State is currently developing a policy based on the state-of-the-practice in other States.

Because of the size of the State and the decentralized nature of the State DOT, **Texas** does not have one single pavement drop-off policy. Each district sets their own standards which they will follow, so practices vary throughout the State. Some districts are making use of the longitudinal taper joint.

(The information in this summary was obtained from a survey conducted by TRB and telephone conversations with each FHWA Division Office's Pavement Specialist.)

REGION 7

In a memorandum dated May 13, 1988, Region 7 strongly encouraged States in that Region to develop policies, mitigating pavement edge drop-offs, conforming to the following guidelines:

1) For "vertical drop-offs of 1 to 2 inches in height. . . consideration should be given to providing appropriate signing and delineation, and limiting drop-off length and time of exposure."
2) Drop-offs from 2 to 4 inches should have a slope of 1:1 or flatter with appropriate warning signs and delineation.
3) Drop-offs over 4 inches should have a 3:1 or flatter drop-off slope and obstruction free area or positive separation.
4) A pavement edge that traffic is expected to cross should not have an effective height greater than 1 inch. Greater heights (up to 3 inches) should be treated with a wedge slope of no steeper than 3:1. The TCP's should provide for a reduced speed limit of 35 mph.

The Region further. stated that each situation should be thoroughly and individually analyzed, taking into account cross section features, traffic volume and mix, speed, and practicality and feasibility of the treatment options.

The four States in this Region, Iowa, Kansas, Missouri, and Nebraska have essentially complied with the guidelines recommended by the Region. The State of Kansas has proposed that all lifts have a 1:1 wedge and uses channelizing devices at spacings equal to twice the speed limit. The State of Missouri allows a 2-inch height differential (their maximum lift thickness is 1 3/4) before they require any kind of treatment on both traversable and non-traversable sections.

(The information for this summary was obtained from a survey conducted by TRB and a survey conducted by Region 7.)

REGION 8

Most of the States in Region 8 have developed a formal policy mitigating edge drop-offs.

The State of Colorado allows a 1 inch, untreated, maximum drop-off height. Any drop-off exceeding 1 inch, and exposed to traffic, must use a 3:1 slope joint at the longitudinal edge. They also require appropriate signing throughout projects where drop-offs occur.

In the State of Montana all longitudinal joints greater than 3/4 of an inch in height must have a 5:1 tapered longitudinal joint.

In North Dakota, although there is no policy, drop-offs are generally limited to 1.5 inches in height and pavement in adjacent lanes must be matched within 24 hours.

The State of South Dakota has a policy limiting the height of drop-offs to 2 inches and requiring adjacent lanes of pavement to be matched within 24 hours. On multi-lane highways traffic is kept off the joint entirely. Appropriate signing is required where ever drop-offs occur.

Although Utah allows up to 4-inch drop-offs, pavement in adjacent lanes must be matched by the end of the day so that no drop-off is left exposed overnight. A sloped 3:1 wedge at the longitudinal joint is sometimes used.

In the State of Wyoming any paving operation that creates a drop-off of more than 1 inch shall have pavement in adjacent lanes be matching by the end of the day. In situations where this is not possible a 3:1 longitudinal sloped joint is used.

(The information for this summary was obtained from a survey conducted by TRB and from Wyoming State specifications.)

REGION 9

No State in Region 9 has developed a formal policy mitigating the hazard of pavement drop-off.

The State of Arizona uses a 4:1 wedge joint at the longitudinal pavement edge between adjacent lifts. A study performed by Arizona DOT has shown that superior compaction is obtained at the joint with this technique. They use warning signs when the vertical difference between lanes is between 1 to 3 inches and cones, drums, or barricades when the difference is greater than 3 inches.

California is currently working on a drop-off policy for their State. As a general practice they allow a maximum drop-off of .15 feet (1.8 inches) between lifts. They require appropriate signing where drop-offs exist.

Although they do not have a formal policy, the State of Hawaii generally does not allow drop-offs to exist overnight by requiring the full travel way to be paved daily. There is usually no more than a 3 inch height difference between lifts. The longitudinal sloped joint is sometimes used at the discretion of the engineer.

The State of Nevada has no formal policy concerning maximum allowable drop-off height. The length of an exposed drop-off can not extend beyond the length of 1 days paving. Appropriate signing is required on projects where drop-offs exist.

(Information for this summary was obtained from a survey conducted by TRB and from Region 9 Pavement Specialist.)

REGION 10

The States in Region 10 treat edge drop-offs differently.

Alaska at present has no formal policy dealing with drop-offs, however they are currently working on one. As a general practice they allow drop-offs to exist for one day's paving operation and allow for a maximum drop-off height of 2 inches.

The State of **Idaho** has no formal policy concerning edge drop-off heights. Drop-offs are handled on a job-by-job basis at the discretion of the engineer. They do require appropriate signing where drop-offs exist. On resurfacing projects the lifts are generally 3 inches thick. In the past Idaho has used the sloped longitudinal joint, but it is not now included in the specifications.

In **Oregon** if the drop-off height is greater than 2 inches then the pavement in adjacent lanes must be matched by the end of the day or a 10:1 sloped wedge must be used at the longitudinal joint. The joint is then cut back to a vertical face when paving resumes. If the drop-off is between 1 and 2 inches in height then adjacent lanes of pavement must be matched within 24 hours.

In **Uashington** the general practice is to have drop-offs not exceed .20 feet (2.4 inches) in height where exposed to traffic. When drop-offs exceed this height channelizing devices are required. The State requires pavement in adjacent lanes to be matched within **24** hours. They also require appropriate signing where exposed. drop-offs exist.

(The information for this summary was obtained from a survey conducted by TRB and information collected by Region 10.)

CONCLUSION

In general, the various State highway agencies have attempted to set some limits in height and length for drop-offs on resurfacing projects. Recently these limits have come in the way of formal policies issued by the State. Forty percent of the States have developed formal policies at this point in time, with several more currently working on such policies. In nearly all cases, these policies conform with the suggestions in the memorandum issued by the Construction and Maintenance Division in December of 1986. While these policy statements mostly refer to resurfacing projects, it is felt that the Z-inch criteria could be used as a standard for milling and excavation type projects and even as a criteria for maintenance.

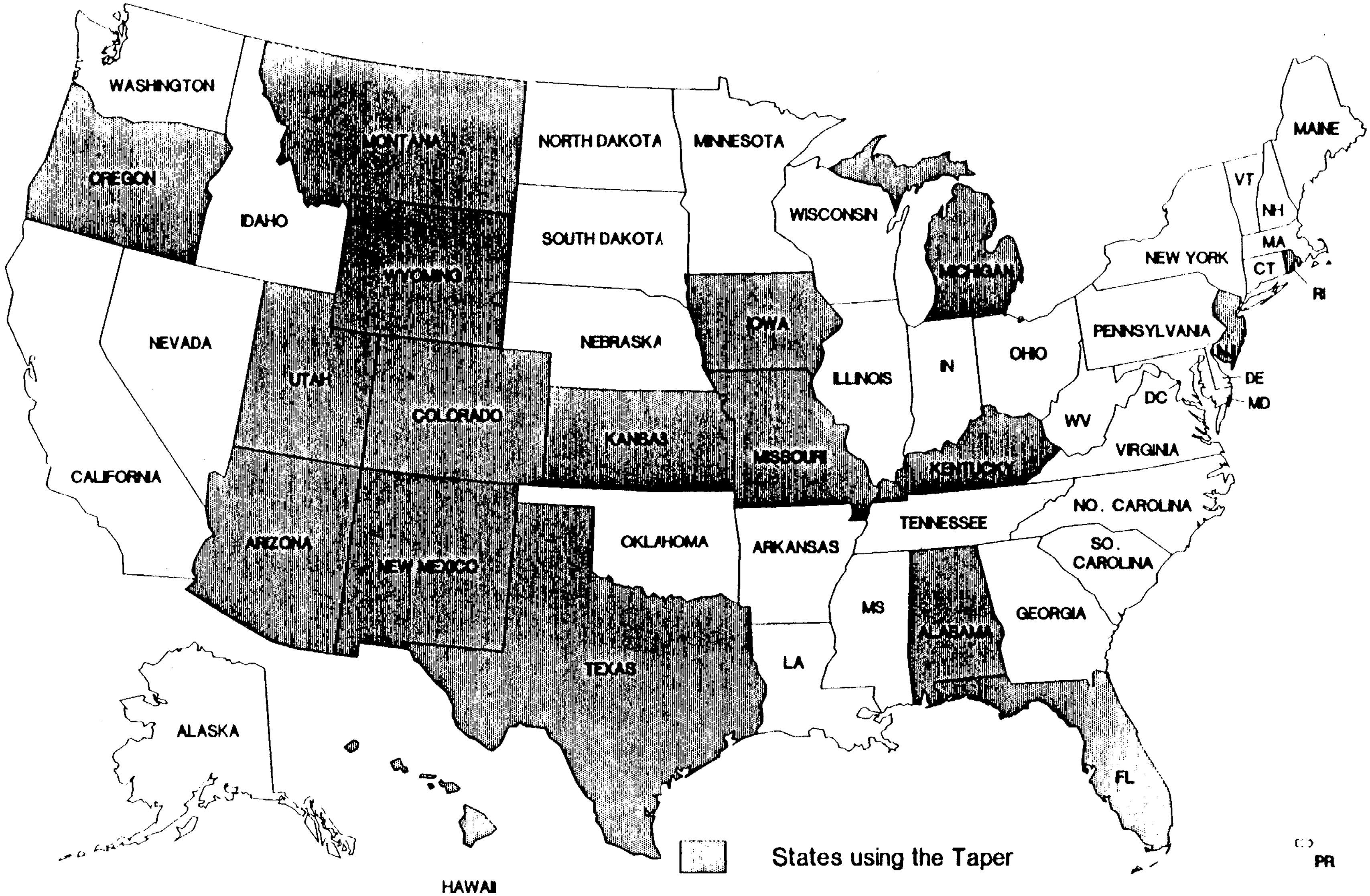
LONGITUDINAL JOINT CONSTRUCTION METHODS

The original intent of the TRB questionnaire sent out to State agencies in 1987, was to determine the state of the practice with longitudinal joint construction with flexible pavements. One practice that is growing in popularity is the use of a longitudinal wedge joint between adjacent lifts of asphalt. Several States already use a tapered edge when a longitudinal edge is exposed to traffic (see figure 2). Studies have demonstrated (see literature review) the safety benefits from the use of such a treatment. In many cases before the adjacent lane is placed, the wedge is cut back to a vertical edge for the joint between lifts. Recently some state highway agencies, namely Arizona and New Jersey, have experimented with the use of the tapered edge as the joint itself as opposed to the more common vertical butt joint. In the research which has been performed, both States claim to get a superior joint with the tapered edge, or "wedge edge." Higher and more uniform densities have been consistently obtained in the area of the joint which is believed will result in a longer pavement life. The tapered joint is expected to yield improved rideability because fewer transverse joints would be required in the pavement. This is because the pavers would not be required to be pulled back at specified lengths for the paving of adjacent lanes, in order to maintain matching pavement requirements normally associated with the use of vertical butt joints.

The State of Arizona originally used a 6:1 sloped wedge, but this has changed to a 4:1 wedge. It is formed by a sloping shoe attached to the paver in order to form the joint. The face of the wedge joint is compacted with a pneumatic tired roller, and then the adjacent lane is paved to finish the joint. The state of New Jersey uses a steel plate attached to the paver forming a wedge of 3:1 slope. The joint face is not compacted, but it is heated with an infrared heater immediately preceding the placement of the adjacent lift, for better bonding. For more information, the reader is encouraged to contact the previously mentioned State highway agencies.

From the research which has been performed to date in this area, the "wedge edge" appears to be a viable solution to the drop-off problem on paving and resurfacing type projects. Instead of creating problems with joint construction it has been shown to yield many desirable benefits.

Usage of Tapers as Longitudinal Edge Treatments



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Memorandum

U.S. Department of Transportation
Federal Highway Administration

Washington, D. C. 20590

Subject Guidelines for Mitigating Pavement Dropoffs in Construction and Maintenance Work Zones

Date DEC 1 1986

From Chief, Construction and Maintenance Division
Office of Highway Operations

Reply to Attn of HHO-31

To Regional Federal Highway Administrators
Regions 1-10
Direct Federal Program Administrator

One of the problems noted during our 1986 construction reviews and work zone safety reviews involves pavement dropoffs adjacent to construction and maintenance activities. These dropoffs include those created by pavement or bridge deck removal work, shoulder excavations, and the placement of new 1 ayers of pavement. When not properly addressed, dropoffs may lead to an errant vehicle losing control resulting in property damage, injury, and possibly death. It was found that many States do not have any policy or guidelines addressing this hazardous situation. With the growing number of 3R/4R projects, there is potential for dropoff incidents to increase significantly.

To address this concern, information has been compiled and used to develop steps to mitigate potentially hazardous dropoffs. These suggested procedures are based on findings from recent research, current policies and guidelines from a nunber of States, and consideration of construction operations. The information presented here is not Intended in any way to represent policy or to serve as a directive of the FHWA, nor does it represent or promulgate any new standard. Instead, this infonnation is to provide guidelines to States in the development of their own dropoff policy.

Any dropoff is considered hazardous, but those greater than 2 inches, left overnight, and immediately adjacent to traffic have a high accident potential.' For such situations, one or a combination of the following mitigating measures is recommended:

1. Specify that the contractor schedule resurfacing or construction operations such that no dropoff is left unprotected overnight, or, as a minimum, limit the length of the dropoff and the period of exposure.

2. If feasible, place steel plates to cover an excavation or trench, A wedge of material around the cover may be required in order to assure a smooth transition between the pavement and the plate. Warning signs should be used to alert motorists of the presence of steel plates particularly when the plates are on the travel lanes.

3. Place a wedge of material along the face of the dropoff. The wedge should consist of stable material placed at a 3:1 or flatter slope. Warning signs may be needed in advance and throughout the treatment. Pavement markings or markers are useful in delineatlng the edge of the travel 1 ang.

4. Place channelizing devices along the traffic side of the hazard and maintain a 3-foot wide buffer between the edge of the travel lane and the dropoff. The minimun spacing of the devices in feet should be, at most, twice the speed in miles per hour. Dropoff warning signs should be placed in advance and throughout the dtopoff treatment.

5. Install portable concrete barriers or other acceptable positive barriers with a 2-foot buffer between the barrier face and the traveled way. An acceptable crashworthy terminal or flared barriers are required at the upstream end of the section. For nighttime use, the barriers must he supplemented by standard delineation devices, i.e., paint, retroreflective tape, markers, or warning lights.

For dropoffs greater than 6 inches, recommendation 5 is strongly suggested if recommendations 1 or 2 are not feasible. Speed reduction measures need to be considered particularly for recommendations 4 and 5. Although these mitigating measures are directed to nighttime conditions, dropoffs must also be properly addressed during daylight operations.

We recognize that there may be some reluctance by the States to develop a dropoff policy or guidelines. The primary concern that has been stated in the past is that the development of such a policy would increase the potential for tort liability actions. It has however also been stated that the existancc of properly developed policies and conformance to those policies can in fact provide the State with a good defense against tort 1 iability. More important however, is that such policies will provide greater protection from accidents and injuries for the motorist.

We strongly encourage you to work with the States on the development of such policies. If any further information or technical assistance is needed, please contact us at your convenience.

for Bob B. Myers

TRANSPORTATION RESEARCH BOARD
COMMITTEE ON FLEXIBLE PAVEMENT DESIGN

COMPILATION OF QUESTIONNAIRE ON LONGITUDINAL JOINT CONSTRUCTION

The questionnaire on longitudinal joint construction vas developed to determine practices and concerns of leaving an open joint vhen paving. The questionnaire focused primarily on safety to the traveling public and joint durability. A copy of the questionnaire is attached.

Responses vere received from 45 states, 2 turnpike agencies, and 4 Canadian Provinces. The compilation of these responses follovs.

Thirty-five agencies allov step-offs (open faces) for nev construction and thirty-three ● llov them on resurfacing. Of the 26 agencies alloving this practice and having a maximum step-off, 62% have a maximum of 2"; 19% have a maximum of 1 1/2"; and only 15% ● llov 3" or more. Five agencies require a taper and this varies between 3:1 and 10:1. Twenty-nine agencies have a maximum time limit of 1 day or 24 hours over which to pave the ● djacmt lane. The others have no specified time limit.

The question ● ddresalng signing required ansvers vhich vere somevhat hard to compile because the Manual of Uniform Traffic Control Devices (MUTCD) has no standard sign for a lane step-off or uneven paving. Therefore, ● isinformatlve signs or, more often, signs that ● ra designed by the agency are used to alert the public of the step-off. Six agencies use the standard signs of Lov Shoulder (W8-9A) or No Passing (W14-3). Fourteen agencies use special signs vith 10 either stating or illustrating Uneven Pavement, 3 state Abrupt Edge and one says Center Line Drop Off. Thirteen agencies use no signs mentioning the step-off.

Of 32 agencies requiring special longitudinal joint techniques, one or more of the folloving techniques are used.

Hatching shoe	53%
Tacked joint	53%
Cutback to vertical face	38%
Taper	19%
30' ski	6%
Joint heater	3%

Several agencies stated that tacking or cutting back to 8 vertical face vu rquired, <u>if necessary</u>.

The agencies that do not allov an open joint require the contractor to move the paver back and square up daily vhcn paving under traffic. For *nev* construction, full vidth paving and paving in echelon are generally alloved as alternatives to moving the *paver* back daily.

No agencies reported any special density requirement on a joint. One is attempting to develop a joint density specification.

Thirty-eight of the agencies responded that they have no specified methods to prevent rounding of the joint edge by traffic. Nine (18%) do not rrllov any traffic on the joint at any time.

The question requesting the responders opinion as to hov hazardous a step-off is to various vehicles drrv some interesting responses. One responder invoked the fifth amendment. The ratings are listed belov. Many responders assumed the "no" column, left in through a design flav, to mean "not hazardous" and thus resulted in an additional rating to that intended.

	Rating			
Hazardous to :	Extremely	Somcvha t	Slightly	Not
Tractor Trailers	6	14	18	10
Passenger Cars	7	20	15	6
Compact Cars	16	19	10	3
Ho totcycles	32	10	6	0

This response is in line vith anticipated results. Motorcycles and compact cars are thought to be the most affected and tractor trailers the least affected.

The question concerning special procedures or deviations did not drav my comments not already Included in the compilation. Likevise, the question requesting special joint edge shapes only provided information on tapers, vhich has already been categorized.

CONCLUSIONS

1. Almost 2/3 of the agencies responding allov step-offs.

2. Tventy-five of the tvmty-six agencies 8lloving step-offs, permit 1 1/2" or greater.

3. a) There is no standard sign for a lane step-off in the Manual of Uniform Traffic Control Devices (MUTCD).

   b) In the absence of 8 MUTCD approved sign, many different signs, some misinformative, are used.

4. The use of a matching shoe and a tacked joint are the tvo most often used special longitudinal joint requirements.

5. Most respondents feel that the hazard of a step-off affects motorcycles more than cars or trucks. Of cars or trucks, compact cars are felt to be most severely affected.

RECOMMENDATION

The only recommendation that is apparent from this compilation is that a need exists for the National Committee on Uniform Traffic Control Devices to approve a standard sign vhich can be used for pavements vith step-offs.

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: ACTION: Life-Cycle Cost Analysis

Date: SEP 15 1992

From: Chairman, PMCG

Reply to Attn of: HNG-42

To: PMCG Members (See Attached List)

A Life-Cycle Costing (LCC) **Task Force** has been formed in response to LCC interest expressed by the **FHWA** Research and Development Executive Board at its 1991-92 winter meeting. The Task **Force** consists of representatives from the Associate Administrators for Policy (HPP-12), Research **(HNR-20)**, Program Development **(HNG-42)**, Motor Carrier **(HIA-20)**, and Administration (HCP-22). The Task Force mission is to develop recontnendationt for the Research and Development Executive Board on appropriate ways to incorporate LCC analysis into the Federal-aid highway **program**, as well as the **necessary LCC research**, development, and training needs.

Attached for your review and **comments** is a draft of the Task Force's **preliminary** study paper, "Life-Cycle Costing and Life-Cycle Cost Analysis: Applications Within FHWA and The Federal-aid Highway Program." We are scheduling a presentation and discussion period of the Task Force's initial effort at the next PMCG meeting. We are seeking PMCG reaction, input and suggestion for improvement necessary to obtain PMCG endorsement of a course of action prior to presenting 'the task force findings to the Executive Research Review Board on October 22.

We would appreciate receiving your comments by September 28. Mr.. Jim Walls has been designated to coordinate'this effort and is available to address any questions you may have or clarify any proposals contained in the preliminary study. Mr. Walls can be **reached** at 366-1339.

Louis M. Papet

PMCC Members:

Lou Papet	HNG-40
Richard Torbik	HEP-10
Tom Pasko	HNR-1
Doug Bernard	HTA-1
Madeline Bloom	HPP-1
Dave McElhaney	HPM-1
John Grimm	HIA-1
W. Mendenhall, Jr.	HRA-06
Byron Lord	HNR-20
Paul Teng	HNR-40
Don Fohs	HNR-30
Ted Ferragut	HTA-20
Dick McComb	XTA-2

Life Cycle Costing and Life Cycle Cost Analysis: .

Applications Within

FHWA and The Federal-aid Highway Program

Preliminary Study
August 1992

Task Force Members:

Jim Walls HNG-42 (Pavements)

Byron Lord HNR-2Ø (Research)

Walt Manning HPP-12 (Policy)

Dennis Miller HIA-10 (Motor Carrier)

Frank Waltos HCP-32 (Contracts and Procurement)

Executive Summary

In response to interest expressed by the FHWA Research and Development Executive Board in Life-Cycle Costing (LCC), **the** Pavement Management Coordinating Croup (PMCG) established an internal LCC Task Force consisting of representatives from the major **affected· Associate** Administrators. The Task Force was specifically charged with developing **recommendations** on appropriate LCC research needs.

Fundamental to accomplishing its primary tasking, the Task Force had to first identify current and potential FHWA LCC applications **along. with** some fundamental policy implications. The Task Force also looked at the LCC implication of the **ISTEA.** This paper includes the Task Force's preliminary efforts in this area.

In terms of its specific tasking on LCC research needs, this paper identifies relevant LCC issues and limitations. It lays out research approach options and a plan of action.

Based on its initial efforts, the Task **F.orce** proposes two separate but concurrent LCC efforts; an internal LCC policy development effort and a two-phase LCC contract research effort. The policy development effort, although internally directed, would most likely require some outside contractor support.

Under Phase I of the contract research effort, FHWA would contract with several companies to provide inter-disciplinary teams to define and clarify LCC issues and necessary research. Phase I work would **incl** udt development of detailed work plans that address the identified LCC research needs. Under Phase II, FHWA would continue to fund **a** more limited number of multi-disciplinary research teams to actually conduct the more promising research activities identified in Phase 1.

The results of this proposed multi-phase research effort and the internal policy development effort would eventually be digested into FHWA guidance on LCC. This final step would most likely be done with in-house staff using consultant support.

The Task Force stresses from the onset that the outputs of life-cycle cost analysis (LCCA) .are not decisions in themselves; but rather inputs into the decision making process.

A draft copy of this paper was circulated to the **PMCG** and discussed a? the **last** July 14 PMCG meeting. The draft paper has been revised to incorporate their views and **comments.**

The Task Force at this point has not made contact with any of **FHWA's** partners and/or customers. Consistent with FHWA's outreach program, the Task Force **suggests that** appropriate outside groups be contacted before research funding decisions art made. Groups such as the American Trucking Association and the Association of American Railroads have conducted research in this area and art likely to have a keen interest in FHWA's efforts. Industry groups such as **NAPA,** AI, PCA, plus ARTBA would also be interested.

Introduction

A Life-Cycle Costing **(LCC)** Task Force was **formed** by Mr. **Louis Papet, Chairman of the PMCG,** in response to LCC **interest** expressed by the Research and **Development Executive Board** at its **1991 - 92** winter **meeting.** The Task Force is **composed** of representatives. from the Associate Administrators for Policy **(HPP-12),** Research (HNR-PO), Program Development **(HNG-42), Motor Carri** er **(HIA-20),** and Administration (HCP-22). Specific Task *Force* members include:

Jim Walls	HNG-42 (Office of Engineering, Pavements Division)
Byron Lord	HNR-2Ø (Office of Engineering, Highway Operations Research and Development, Pavements Division)
Yalt Manning	HPP-12 (Office of Policy Development, Transportation Studies Division)
Dennis Miller	**HIA-10(Motor** Carrier)
Frank **Waltos**	HCP-32 (Office of Contracts and Procurement Research and Special Programs Division)

The Task Force mission is to develop **recommendations** for the FHUA Research and Development Executive Board on appropriate ways to Incorporate **LCC** analysts into the Federal-aid highway program, as well as the necessary LCC research, development, and training needs.

This study paper first defines LCC, LCC analysis, and cost effectiveness. It then discusses potential LCC applications with their **implications. This** discussion is followed by a **summary** of current **policies** and **a** look at new **LCC** mandates. **General** LCC technical and policy related Issues and limitations are then discussed. In the closing sections, the paper **discusses** potential approaches to determining and conducting needed research and training necessary to implement LCCA, and finally, the last section presents **recommendations** on the preferred course of action.

Definitions

Current literature loosely defines life-cycle costing/life-cycle cost analysis as a form of economic analysis which focuses attention on **determining** the longer term economic implications of alternative strategies rather than merely the initial or front end costs of the immediate decision at hand. **It** is a tool that can be used to assist in making economically prudent long-term **expenditure** decisions, i.e. cost-effective investment decisions.

The **Task Force** believes the terms "life-cycle costing' and 'life-cycle cost analysis' are synonymous. However, life-cycle cost analysis is more descriptive of the inherent analytical process and, as a result, the remainder of this paper uses the **term** life-cycle cost analysis **(LCCA).**

A related term, cost effectiveness, also has bearing in terms of FHWA Policy. Cost effectiveness is an economic related measure (generally a ratio) that describes how well an alternative meets a performance type objective in relation to the cost of achieving that performance. The cost component of cost-effectiveness measures should generally reflect life-cycle cost. The attractiveness of using cost-effectiveness measures is based on its ability to tie cost to performance. For example, a cost-effective measure in the safety area might be cost/accident reduced. In terms of pavements, it could be cost per ESAL carried until terminal serviceability is reached.

As well as defining what LCCA and cost effectiveness are, It is equally important to define what they are not. The Task Force stresses from the onset that the outputs of life-cycle cost analysis are not decisions In themselves; but rather inputs into the decisionmaking process.

LCC Applications

The Task Force sees two distinct areas where LCCA could be applied within FHWA, i.e., internal and external applications. The FHWA can use internal applications to support decisionmaking at the national level. External applications are those related to the Federal-aid highway program. Within each area there are multiple application possibilities.

In terms of the Federal-aid highway program, there are several potential decision levels where highway agencies could apply LCCA. These decision levels include but are not necessarily limited to:

State Network Analysis - To evaluate total funding needs and to determine resource allocation levels for the various systems, project categories, or improvement types in relation to established system wide performance goals. The LCCA can also be incorporated into the various management systems required by the ISTEA.

Project Priorititation - To Compare the merits of funding one project in lieu of another.

Pavement Design - To assist in pavement type selection and to evaluate the marginal rate of return for providing premium in lieu of standard pavements.

Materials Specifications - To compare the use of imported premium. aggregate versus lower quality, but locally available. aggregate.

Total Quality Management - To evaluate the long-term impact of increased attention to quality control. For example, increased expenditure for research and testing equipment may quickly pay for itself.

Operational Analysts - To evaluate catch basin clean out policy, the type and application rates of de-icing chemicals, use of cathodic protection, etc.

Current LCC Policy

Internally, the FHUA already incorporates cost-effective considerations in terms of national level policy development and analysis of alternate investment strategies. The Associate Administrator for Policy Incorporates many aspects of life-cycle costing analysis during development of the biennial report to Congress, "Status of the Nations Highway and Bridges.' Some LCC principles have been and more will be included in cost allocation -studies and in developing and evaluating legislative proposals.

Externally, the FHWA does not specifically require State highway agencies (SHA) to conduct life-cycle costing or economic analysis in support of either program or project level decisions as a precondition for federal-aid funding. This is not true for other US DOT Modal Administrations.

The Federal Transit Administration (FTA) requires development of cost-effectiveness measures based on life-cycle cost analysis in support of grant applications for Section 3 discretionary money. This requirement, called an Alternatives Analysis, must be conducted by applicants at the Draft EIS stage, and the results must be included in the Draft EIS. This Alternatives Analysis requirement has been in place for many years, and the FTA has developed and published specific procedural guidelines on how to conduct it.

In contrast, the FHUA has administered a formula based rather than a discretionary program and has encouraged rather than mandated LCCA in the State and local decisionmaking process affecting Federal-aid highway funds. While FHUA will continue to administer a predominately formula based program, FHWA now administers some discretionary programs. The LCC would appear to have a more substantive roll in discretionary programs.

The FHYA, in its pavement policy, requires SHA's to have a pavement management systems (PMS). In that policy, FHWA defines PMS as a set of tools for finding cost-effective strategies.

At its March 8-10 meeting, the Research and Technology Coordinating Committee developed comments on the FHWA R&T program. Among other comments, the committee noted that, " . . . the lack of attention to life-cycle costs and benefits is a major impediment to the utilization of highway related technologies. Particular effort should be made in the research program to develop novel, user-friendly, and robust methods and tools for life-cycle costing'

ISTEA LCC Provisions

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 specifically addresses LCC under sections 134(f)(12) and 135(c)(20). These sections require that the metropolitan and statewide planning processet incorporate consideration of several factors including "the use of life-cycle costs in the design and, engineering of bridges, tunnels, or pavement."

Cost effectiveness is referenced in section 119, 'Interstate Maintenance Program.' Under subsection 4, it establishes eligibility when a 'State can demonstrate . . . that such activities are a cost- effective means . . ."

The ISTEA also addresses LCCA in FTA's Section 3(i) program. The revisions both weaken and strengthen the application of LCC in FTA's Alternative Analysis. While the legislation specifically exempts certain metropolitan. areas from Alternatives Analysis requirements, it strengthened the Alternative Analysts requirements in non exempted areas.

One aspect of the ISTEA that presents somewhat of a dilemma for LCCA is the requirement to develop and implement several management systems. While current experience reveals that PMS's can be used to foster systematic decisions based on life-cycle costs, few if any, explicitly incorporate user costs OP the time value of money. Host focus on maximizing performance based on fixed budgets. Even in those highway agencies that have PMS's in which budget level and performance impact are directly related, the systems have little to do with ultimate budget decisions.

LCC Analysis Issues

Each LCCA application will, to varying degrees, have its own specific LCC issues. However, some of the more obvious fundamental issues include determining:

(a) the appropriate life cycle and analysis periods
(b) the alternatives that should be included
(c) the-performance histories of the alternatives
(d) the cost factors to be included
(e) the actual costs of the various cost factors
(f) the appropriate discount rate --

Procedural issues are also a concern. It include cdncems over how:

(a) inflation is addressed?".
(b) sensitive the results are to the discount rate?
(c) performance history variations are addressed?
(d) Agency Costs and User Costs are incorporated?
(e) SHAs can capture and re-invest user cost savings?

Technical, Policy and Procedural Issues and Limitations

Legitimate Subjective Inputs

Being a form of economic analysis, LCCA has all the strengths, weaknesses, and limitations of traditional economic analysis. Foremost among the weaknesses is the fact that LCCA includes many technical assumptions and policy related positions which directly influence the outcome of such analysis. The assumptions and policy inputs necessary to conduct an analysis can be very subjective and highly susceptible to criticism from all parties impacted by the analysis.

Technical assumptions and policy inputs must be clearly identified along with supporting rational. Rational limits or acceptable ranges should be established for technical inputs and policy related assumptions. Sensitivity analysis should be conducted within the acceptable ranges to evaluate the influence of the parameter being considered.

Alternative Development .

Another **important LCC issue is** assuring consideration of a broad **range** of alternatives. **The LCCA** cannot be used to evaluate **the economic wisdom of a** particular alternative in and of itself. **It can only** evaluate the **relative** merits between **alternatives.** As **such,** incorporating all viable alternatives **is** essential. **This** should include promising **new** approaches and technology. Unfortunately, estimating the **performance** lives of alternatives, is **at** best, both an art and a science even when historical data is available. **Untri**td but promising alternatives inherently incorporate greater risk than the tried and true. This additional risk has to be addressed.

Private industry incorporates risk through **the selection of** appropriate-discount rates. Riskier projects (investments) require prospects of greater (generally **3-5%** more) return. The SHA efforts in developing **PM** Systems and SHRP LTPP research' will develop a better understanding of pavement performance relationships and should help in reducing risk.

Performance Equivalency

Implicit in economic analysis is **the** assumption that performance differences between **alternatives** *can* be clearly defined, captured, and reflected in **the** analytical results. **While** this is true for some aspects, **it** is not always **the** cast. All alternatives which have **the same** 'useful lift," in terms of tither years or loadings, do not **necessarily** provide equivalent **performance** over that "useful life.'

For example, two competing pavtmtnt **rehabilitation** alternatives with the same pavement life, may very well deteriorate differently. If this is the **case,** than **they** will provide different levels **of service** over their useful lives, even if they reach **the same** terminal serviceability at **the same time (see** figurt 1).

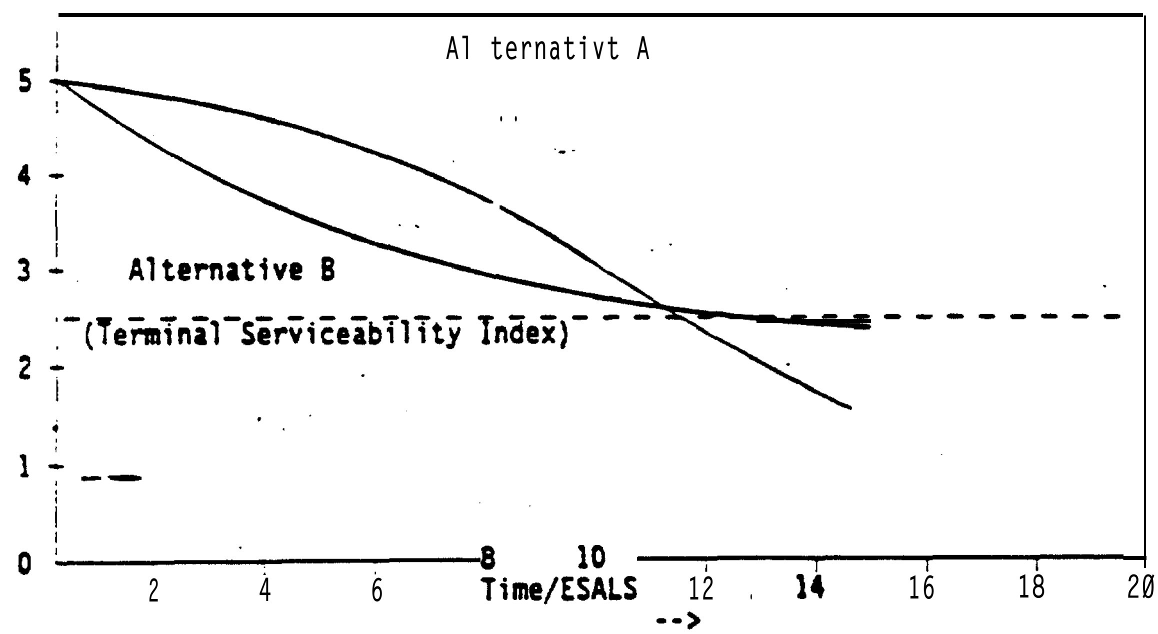

Figure 1 Pavement Performance Histories

N - table and Non-quantifiable

In any economic analysts, there are, generally **speaking,** non- **costable** and **non-** quantifiable **elements that, none-the-less,** need to be considered in the decision making process. **The how** and the degree to **which** the non-costable and non-**quantifiable** elements are addressed is a major Issue. **While** broader scope analysis are **more** complete, they are not necessarily more accurate.

The degree to which current and future costs and benefits can be accurately estimated severely limit the ability of LCCA to distinguish between of alternatives when LCCA reveals little economic difference. When LCCA results are relatively close (within **10-20%** of one another) relative risk and other considerations take on greater significance;

User Costf

Highway user costs, particularly **travel** time or delay cost, have been controversial. **While** they may be difficult to quantify and price, construction imposed traffic delays have become, and are likely to continue to be,, an ever increasing burden imposed on the public.

Currently, highway agencies have little economic incentive to select alternatives that minimize total (agency plus user) LCC. The alternative with the lowest total life-cycle cost may well be the one that has the lowest user cost but, at the same time, the highest agency cost. Because there are no readily available mechanisms **for** highway agencies to **transform** reductions in user costs to additional highway investment capital, the **current** system encourages **highwav** agencies to minimize agency rather than total costs. This tends to result significant sub-optimization of total possible benefits.

This issue is addressed to some **extent** by **requiring full** maintenance of traffic on heavily traveled routes. Highway agencies are already paying a premium on certain projects for limiting the contractors hours of **operation and/or** elaborate traffic detours. Highway agencies need to anticipate this trend and incorporate higher future rehabilitation cost in current life-cycle cost analysis.

Marginal Costs

The LCCA is generally used as a means of **determining** the most economically efficient (some times the cheapest) project from among a set of alternative that adequately meet the minimum performance requirements. This may well be short sighted. Highway agencies need to look at marginal costs, especially when relatively modest total cost increases make significant differences in performance and or service lives. Premium pavements may be economically **justified** in areas with no alternative routes for maintenance,. **rehabilitation,** and/or reconstruction activities.

Discount Rate

As a minimum, model LCCA procedures should incorporate the time **value** of **money** and discount future cost and benefits **to a common time.** As just noted, such procedures must include internal (highway agency), as **well** as external **(user)** costs associated with a highway facility over its intended useful life. Such procedures, however, would have to provide guidance on how to deal with the highway agency's inability to capture user cost saving for future reinvestment.

Procedures

To be practical, LCCA must be conducted using procedures that recognize the policy issues that influence the analysis and explicitly document the policy positions taken in the analysis. The FHWA does not currently have LCCA procedural guidelines. If the FHWA intends to use LCCA internally, it needs to establish procedures governing such applications. If, on the other hand, FHWA expects to encourage consideration of LCCA in State and local highway agency decisions affecting Federal-aid highway funds, FHWA will need to establish LCCA procedural guidelines. From a technical aspect, model procedures should identffy and evaluate all viable alternatives and relevant cost factors. They -should incorporate techniques for developing accurate cost, performance, and service lives of identified alternatives.

Alternate Approaches

While the Task Force has been able to identify areas where LCCA research would be productive, it believes a more comprehensive look at the entire process as applies to highway investment decisionmaking is warranted. The Task Force further believes that integration of the many debatable positions into a cohesive position on the application of LCC and appropriate guidelines on the conduct of LCCA within the FHWA program would be much more positive contribution.

The Task Force also looked at developing an in-house working group to review the literature and identify and conduct the needed research. The Task force believes FHWA does not have sufficient manpower in the appropriate multi-disciplinary fields available to make a significant contribution to advancing LCC within FHYA. LCC embraces many complex issues; some are readily apparent, others are more subtle. Prior to more active FHWA involvement, endorsement, or technical support of LCC, FHWA sponsored research is necessary to:

(1) more clearly define, explore, and resolve identified LCC Issues;
(2) identify and explore other-important LCC issues not currently identified; and
(3) develop a comprehensive approach to incorporate the research findings into integrated procedures for the various LCC applications..

Policy Recommendations

The Task Force recommends that FHWA policy explicitly promote the long-term cost-effective use of, Federal funds, both in its internal operations and in the Federal-aid highway program.

The FHWA should continue to use LCCA and cost-effectiveness considerations in its internal operations to evaluate the condition and performance trend of the Nation's highways, and to determine whether or not we are using resources to the maximum advantage in achieving the national transportation goals. Other internal applications could include developing and analyzing highway investment polic developing and evaluating cost allocation studies, and evaluation of competi IVHS technologies and other R&&activities.

The FHWA-should increase its efforts to encourage, support, and implement State and local use of life-cycle cost analysis principles at all decision levels. It should develop model 'LCC guidelines, building on extensive existing LCCA knowledge base including that of State and local highway agencies. The FHWA should make these LCCA guidelines available to highway agencies and require consideration of LCC in the Urban and Statewide Planning processes. The FHWA should also require the development of LCC and cost-effectiveness information as part of each ISTEA mandated management system.

In response to specific ISTEA LCC requirements, FHWA should focus on program rather than project specific requirements. The FHUA should provide guidance on conducting LCCA, require that it be conducted, and ensure that the results are explicitly considered in the decisionmaking process. It should not become involved in conducting or reviewing/approving actual LCCA's conducted by State and local highway agencies, even on Federal-aid highway program funded projects.

Research Recommendations:

In order to move forward with LCCA, FHWA should initiate research and training, necessary to foster improved LCC analysis at all decision levels. -

Because of the financial/economic focus, the research should be conducted by a multi-disciplinary team that draws on the strengths of economists, financial analysts, and other appropriate disciplines, as well as the highway engineerfr community.

Because of the enormity and complexity of LCCA and the pervasiveness of potential application opportunities, it will be difficult to formulate a comprehensive research work plan with existing in-house resources.

The Task force recommends that FHUA pursue a two-phase LCCA contract research effort as follows:

Phase I - an innovative exploratory research affort.

Phase II - a traditional, in depth,, detailed research effort into specific LCCA issue areas identified in phase I.

Phase I - Exploratory Research

The exploratory research phase would require that selected contractor(s) develop an inter-disciplinary team acceptable to FHWA that would;

1. Explore policy issues and the implications of various FHYA courses of action.

2. Identify specific LCC research needs associated with the courses of action identified.
3. Develop a detailed work plan and cost proposal that addresses the specific research needs identified.

Because of the complexity of LCCA, and the relatively inexpensive cost anticipated for the exploratory research, the Task Force believes it would be extremely beneficial (i.e., cost effective from a LCC perspective) to fund multiple research teams for this early stage research. The Task Force envisions awarding multiple contracts under one primary exploratory research contract. The exact number of exploratory research contracts to bt funded would bt based on the responses received to the request for proposals (RFP).

Phase II - Detailed Research

The Phase II research component it basically designed to carry out the specific research that will be proposed in the detail td work plans dtvtloptd by the inter-disciplinary teams under Phase I. Upon completion of the Phase I exploratory research, FHYA would evaluate the research tram(r) findings and proposed work plans. At that point, FHWA would decide whether to fund of all or part of the research activities identified by one or all the exploratory research contractors. The Task Force envisions the Phase II component would be an option included in the Phase I research contract.

On completion of this proposed two-phase research effort, FHWA will still need to consolidate the various research teams efforts, product LCCA guidelines, and where necessary, develop LCCA policy, technical advisories, and possibly regulations. The Task Force recommends that the final component would be to establish appropriate training program(s).

With the concurrence of the Research and Development Executive Board, the Task Force will establish a LCCA working group to develop an RFP consistent with the preceding recommendations. Preliminary estimates are that an RFP could be ready for early FY 93 Funding. funding for the second phase would not be necessary until FY 94.

2. Identify specific LCC research needs associated with the courses of action identified.
3. Develop a detailed work plan and cost proposal that addresses the specific research needs identified.

Because- of the .complexity of LCCA, and the relatively inexpensive cost anticipated for the exploratory research, the Task Force believes It would be extremely beneficial (i.e., cost effective from a LCC perspective) to fund multiple research teams for thls early stage research. The Task Force envisions awarding multfplt contracts under one primary exploratory research contract. The exact number of exploratory research contracts to be funded would be based on the responses received to the request for proposals (RFP).

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Federal Highway Administration

[FHWA Docket No. 94–15]

Life-Cycle Cost Analysis

AGENCY: Federal Highway Administration (FHWA), DOT.

ACTION: Interim policy statement; request for comments.

SUMMARY: This FHWA policy statement on life-cycle cost analysis (LCCA) helps fulfill Federal management responsibilities for analyzing life-cycle cost aspects of infrastructure investment decisions under Executive Order 12893, "Principles of Federal Infrastructure Investment." The policy statement establishes LCCA principles to be applied by FHWA in infrastructure investment analyses, and in evaluating the adequacy of State highway agency procedures used in conducting required LCCA for investments funded through the Federal-aid highway program. States md local agencies are expected to apply these principles in evaluating program and project level investment decisions involving Federal-aid highway funds as required under applicable FHWA regulations. Comments are solicited on potential problems in implementing provisions of this policy statement and specific needs for training and technical assistance in LCCA.

DATES: This interim policy statement is effective on July 11.1994. Comments on the interim policy statement must be received on or before October 11, 1994. A final LCCA policy statement will be published that takes into consideration comments received on this interim statement.

- s u b m i t written, signed comments concerning this interim policy statement to FHWA Docket No. 94–15, Federal Highway Administration, mom 4232, HCC–10, Office of the Chief Counsel, 400 Seventh Street, SW., Washington D.C. 20590. In addition to specific comments on this policy statement, comments are requested on training and technical assistance needed to implement LCCA. All comments received will be available for examination at the above address between 8:30 a.m. and 3:30 p.m. e.t. Monday through Friday, except legal Federal holidays.

FOR FURTHER INFORMATION CONTACT: MI. James w. March, Chief, Systems Analysis Branch, (202) 366–9237, or Mr. Steven M. Rochlis, Legislation and Regulations Division, (202) 366–1395, Federal Highway Administration, 400 Seventh Street SW., Washington D.C. 20590.

SUPPLEMENTARY INFORMATION:

Background

There is an increasing recognition that total life-cycle costs of highway and transportation investments must be given greater consideration in all phases of highway programs. Executive Order 12893, "Principles of Federal Infrastructure Investment," requires that benefits and costs of infrastructure investment be measured and appropriately discounted over the full life cycle of each project. Sections 1024 and 1025 of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) (Pub. L. 102-240.105 Stat 1914, 1977) also require consideration of "the use of life-cycle cost in the design and engineering of bridges, tunnels, or pavement." Subpart B of the interim final rule on implementation of ISTEA management systems (23 CFR 500.207) requires use of LCCA for pavement management systems (PMS) and Subpart C (23 CFR 500.307) requires use of LCCA or comparable techniques for bridge management systems (BMS).

Life-cycle cost analysis is an economic evaluation of all current and future costs associated with investment alternatives. It is a valuable economic analysis technique for evaluating highway and other transportation programs and projects that require long-term capital and maintenance expenditures over the extended lives of facilities. Future costs are discounted using an appropriate discount rate to compare costs incurred at different points in time.

Life-cycle cost analysis principles and techniques are used in many types of economic analysis to compare benefits and costs arising at different points in time. Benefit-cost analysis and cost effectiveness analysis, for instance, use life-cycle cost analysis principles to discount future benefits and costs of investment alternatives over the lives of alternatives being evaluated.

Life-cycle cost analysis is used to evaluate programs of pavement and bridge improvements as well as individual projects. It is an important input to estimates of future funding requirements and to the development of improvement programs, especially when there are budget constraints.

The use of value engineering is receiving increased attention as a technique for analyzing the functions of a program, project, system, product, or service to identify opportunities to significantly lower costs while still achieving the essential functions. Life-cycle costs are often analyzed to ensure that unnecessary costs are avoided by considering future operations, maintenance, and reconstruction requirements.

Total life-cycle costs of specific facilities may be many times the initial construction costs when user costs are considered. It is essential that a long term perspective be taken in programming improvements, selecting among alternative maintenance, rehabilitation, and reconstruction strategies, and designing pavements, structures, and other highway elements. Longer design lives may have to be considered, and traditional strategies for programming maintenance and rehabilitation activities may have to be reevaluated to determine whether they adequately consider future costs, including user delay-related costs.

Increasing congestion on important highways in urban areas and some rural areas makes it critical to fully consider life-cycle costs of investment decisions. Safety concerns and auxiliary construction costs to maintain, rehabilitate, or reconstruct congested highways and bridges under traffic are very high. User costs and delays around work zones in congested areas may be even higher and represent significant inefficiencies that may adversely affect economic productivity, especially on the National Highway System (NHS). These delays can erode productivity gains realized by the growing number of industries using just-in-time and other advanced logistics strategies that depend on efficient and predictable transportation.

Regardless of whether user costs are included in a formal LCCA, most States already implicitly consider user costs when they choose to pay premiums to maintain traffic through work zones or design more durable pavements in congested urban areas. Including user costs in LCCA makes these implicit considerations explicit, and may help identify other opportunities to reduce overall agency and user costs.

Recognition of the high future costs to maintain and rehabilitate highways, bridges and tunnels, and their associated traffic control, safety, environmental, and hydraulic components has led to increased interest in the potential for LCCA to improve investment productivity and reduce public and private costs of highway and other transportation programs. The FHWA and the American Association of State Highway and Transportation Officials (AASHTO) jointly sponsored a symposium in December 1993 to learn more about LCCA practices among the States and to identify research, training, technical assistance, and policy-related needs to improve LCCA application. An important input to that symposium was an AASHTO survey of State LCCA practices.

Many specific LCCA issues and research needs were identified at the symposium. Key technical issues included how to establish the appropriate analysis period, how to value and properly consider user costs, and how to choose the appropriate discount rate. Participants also identified important research and data needed to predict pavement and bridge performance and forecast future traffic.

An important policy issue raised at the symposium was the recognition that results of LCCA may favor selection of improvements with higher initial costs in order to achieve significant long term savings in overall investment requirements. It may indicate, for instance, that more projects warrant reconstruction rather than rehabilitation strategies, that early intervention with preventive maintenance is cost effective, or that somewhat higher designs or levels of service may be appropriate for some facilities. The FHWA recognizes that LCCA, thus, may result in proposals for greater expenditures up front. At the same time virtually all transportation agencies will continue to face budgetary limitations at least over the short term. Life-cycle cost analysis will help agencies identify and explain the real costs borne by transportation users of inadequate infrastructure funding. Furthermore, LCCA can assist agencies that face fiscal constraints in making the best use of available funds. Several States already use LCCA in developing network improvement programs as part of their pavement and bridge management systems. Eventually it is desirable for all States to have such capabilities.

The following paragraphs highlight key principles of good LCCA practice. Applying these principles generally will allow States and local agencies to identify investment alternatives that will minimize total life-cycle costs. While their use is not mandatory in all [redacted], States are strongly encouraged to apply these principles in conducting life-cycle cost analyses unless there are unique characteristics of particular programs or projects that require principles to be modified. Life-cycle cost analysis, of course, is only one consideration in many investment decisions, but it certainly is one of the most important for NHS routes and other high volume roads in light of the costs and lost productivity associated with future maintenance and rehabilitation actions.

In general there are no hard and fast rules concerning the appropriate length of the analysis period. The analysis period will vary depending on the type of improvement (bridge, versus tunnel, versus pavement), the location (urban versus rural), the highway system (NHS versus other), and the design lives of all appropriate alternatives. In general, longer design lives should be considered for improvements on the NHS and other high volume urban roadways because future agency and user costs associated with maintenance and rehabilitation activities may be so high. For pavement improvements on the NHS, design lives of 50 years may be reasonable while bridge and tunnel improvements may have design lives of

100 or more years. The consideration of longer design lives will require longer analysts periods in LCCA. Analysis penods for projects involving other modes generally should he long enough to cover the full life-expectancy of the investment-the time until facilities would have to be reconstructed if initially constructed to an optimum design. These lives would vary according to the modal alternative being examined. Analysis periods for all protect alternatives should be the same length.

The inclusion of user costs in LCCA is particularly controversial among some States. Part of the controversy over user costs is the fact that they often are many times higher than agency costs and can critically influence decisions. While all motorists do not value costs of delays as highly as do commercial travelers, the costs and lost productivity to businesses of delays around work zones are simply to0 high to ignore. In fact, such dekys arguably have a greater impact on business than delays associated with inadequate capacity because businesses factor normal congestion costs into their plans; but delays around work tones generally Cannot be foreseen and thus are more disruptive. Technical advisories to be developed on estimating user operating and delay costs will address this issue in greater detail.

In addition to increased delay and vehicle operating costs, rehabilitation and maintenance activities may result in increased accident costs around work zones. [illegible] dviaoriea will be developed to assist in estimating increases in accident rates associated with different types of rehabilitation and maintenance ● ctivitia. The most comprehensive information on the costs of motor vehicle accidents is contained in the National Highway Traffic Safety Administration's publication. "The Economic Cost of Motor Vehicle Crashes, 1990." A copy of this document is ● vaiiabie in the public docket for this notice.

The proper use of the discount rate has been an issue for LCCA, cost-benefit analysts and other types of economic analysis as well. Among the issues are the relationship between the discount rate and inflation, factors that affect the choice of rates, and how to establish rates over a long analysis period. Office of Management and Budget (OMB) Circular A-94, "Guidelines and Discount Rate for Benefit-Cost Analysis of Federal Programs," provides guidance on selecting appropriate discount rates for economic analyses. Since the choice of discount rate Can affect relative life-cycle costs, sensitivity analysis may be appropriate if hvo or more alternatives are close in cost, if streams of costs and benefits among alternatives vary significantly over time, or if the discount rate is outside the range of discount rates recommended by OMB.

The FHWA will deveiop training and technical assistance materials to address issues in LCCA. These materials should supplement guidance on economic analysis techniques contained in AASHTO's 1977 publication. "A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements,"[1] the "Red Book," in the forthcoming update to that publication which was developed under National Cooperative Highway Research Program Project 7-12, and in other guidance on LCCA issues. While additional materials are being developed, this interim policy statement provides guidance on LCCA principles applicable to highway and structure design.

The FHWA is reviewing its policy on alternative bridge designs (53 FR 21637, June 9.19661 for consistency with this interim life-cycle cost analysis policy as well as with Executive Order 12893.

Policy

The following is FHWA's LCCA policy for infrastructure investment analyses. It represents good practice that should be followed by States and local transportation agencies in making program and project investment decisions:

1. Life-cycle costs are an important consideration in all highway investment decisions.

2. The level of detail in LCCA should be commensurate with the level of investment involved and the types of alternatives being analyzed. Investments on the NHS generally warrant mom detailed analysis than investments on non-NHS routes. Similarly, evaluation of decisions whether to reconstruct or rehabilitate a facility warrants more detailed analysis than consideration of alternative maintenance strategies.

3. Typical life-cycle cost analysis profiles may be developed rod used as the basis far evaluating alternatives for general types of improvements, such as, consideration of alternative pavement designs or different types of bridges on various functional class highways. Major programs and projects, however, often will require consideration of a broad range of alternative rehabilitation and reconstruction opoons and more detailed analysis of potential alternatives. The potential applicability and use of LCCA profiles will be discussed in greater detail in future technical advisories.

4. Other factors, including budgetary, environmental, and safety considerations, legitimately influence highway investment decisions and should be considered along with the results of LCCA in evaluating investment alternatives. Life-cycle cost analysis principles should be used in conjunction with other appropriate economic analysis techniques in pavement and bridge management systems. Systemwide or network objectives as well as project level concerns should be considered in decisionmaking, and both levels of analysis should consider life-cycle costs.

5. Analysis periods should be for the life of the facility or system of facilities being evaluated and should ● cwunt for costs of foreseeable future ● uions. Analysis periods should not be less than 75 years for major bridge, tunnel, or hydraulic system investments, and not less than 35 years for pavement investments. Longer design lives may be ● ppmpriate for the NHS or other major routes or corridors.

6. All ● ppr0ptita agency costs anticipated during the analysis period should be considered in the analysis, including traffic control costs during maintenance and rehabilitation, costs of special construction procedures required to maintain traffic, and agency operating costs for such things as tunnel lighting end ventilation. In those cases wbem the agency required to operate a facility is not the one making the investment decision, it is important *for the funding* agency to include operating costs *borne by* other organizations responsible for operating the facilities.

7. User costs including increased vehicle operating costs, ● CCident costs, and delay-related Costs incurred throughout the analysis period should be considered in LCCA. Increased costs due to deteriorated riding surfaces, circuitous routings, and accidents and dekys around and through maintenance and construction work zones are all important.

8. Future agency and user costs should be discounted to net present value or converted to equivalent uniform annual costs using appropriate discount rates. Discount rates selected should be consistent with guidance pmvided in OMB Circular A-94.

[1] This document is available for inspection as prescribed at 49 CFR Part 7, Appendix D. It may be purchased from the American Association of State Highway and Transportation Officials, 444 N. Capitol Street, NW., Suite 225, Washington DC 20001. A copy also will be available in the public docket for this notice.

Technical advisories on these and other technical issues in the application of LCCA will be issued by FHWA in the future.

Issued on: June 30, 1994.

Rodney E. Slater,

Federal Highway Administrator.

[FR Doc. 94-16719 Filed 7-8-94; 8:45 am]

BILLING CODE 4910-22-P

Memorandum

U.S. Department
of Transportation
Federal Highway Administration

Subject: **INFORMATION:** 1991 Inter-modal Surface **Transportation** Efficiency Act **(ISTEA)** Implementation Interstate Maintenance Program

Date: MAY 21 1992

From: Associate Administrator for Program Oevelopment

Reply to Attn of: HNG- 13

To: Regional Federal Highway Administrators
Federal Lands Highway Program Administrator

The purpose of this memorandum is to provide written guidance regarding the provisions in the 1991 **ISTEA** which created the Interstate maintenance **(IM)** program.

Authorizations - Section 1003

Section **1003(a)(1)** establishes the first annual authorizations for the IM program for FY 1992 through FY 1997, in amounts ranging from $2.431 billion to $2.914 billion.

Apportionments - Section 1009

Section 1009 modified Section 104(b)(S)(B) of Title 23, which previously established the apportionment formula for the I-4R program. The formula remains based on the same factors, lane-mile (55 percent) and vehicular miles of travel (45 percent), for apportioning IM funds, but the formula now includes those Interstate routes designated under Sections 103 and 139(c) of Title 23 plus Interstate routes designated under 23 **U.S.C.,** Section 139(a) before March 9, 1984 (except toll roads not **subject** to a secretarial agreement as provided in Section 105 of the Federal-Aid Highway Act of 1978). Section 104(b)(S)(B) of Title 23 provides that no State shall receive less than one-half percent of the total **IM** funds apportioned annually.

The certificate of apportionment of FY 1992 funds was transmitted by the FHWA Notice N 4510.264 dated December 18, 1991.

Availability - Section 1020

Section 1020(a) rewrites 23 U.S.C. 118 and provides that **IM** funds shall remain available for obligation in a State for a period of 3 years after the last day of the fiscal year for which they are authorized. For example, FY 1992 funds were apportioned on December 18, 1991, and will lapse on September 30, 1995, and FY 1993 funds will be apportioned on October 1, 1992, and will lapse on September 30, 1996.

Federal Share - Section 1021

Section 1021(a) provides that the Federal share on all IH projects shall be 9Ø percent, except as modified in States with sliding scales.

Eligibility - Section 1009

Section 1009(e)(S) amends 23 U.S.C. 119(a) to permit the Secretary to approve IM funded projects for resurfacing, restoring, and rehabilitating routes on the Interstate System designated under Sections 1Ø3 and 139(c) of Title 23, and routes designated prior to Hatch 9, 1984, under Section 139(a) and (b) of Title 23.

Section 1009(e)(3) amends Section 119(c) of Title 23 to establish types of work eligible for IM funding. The section has been interpreted to include as eligible, those work items which provide for 3R work on existing features on the Interstate route and its interchanges and grade separations within normal 'touchdown limits." For example, the rehabilitation of existing roadside hardware may include IM funding for work such as bringlnq old guardrail up to current standards, maintenance of impact attenuators, refurbishing existing traffic control signs, pavement markings, and other devices, etc. However, excluded from eligibility for IM funding are all new work elements, such as new interchanges, new ramps, new rest areas, new noise walls, or other work which does not resurface, restore, or rehabilitate an existing element.

Existing bridges (including over crossing structures) may be replaced with IM funds, provided they meet the structurally deficient criteria of the bridge program. Bridges classified as functionally obsolete may also be replaced with IM funding, except that capacity expansion elements should be subject to the limitations discussed in the following paragraphs.

Section 1009(a) prohibits IM funding for the portion of the cost of any project attributable to the expansion of the capacity of any Interstate highway or bridge, except for the addition of high-occupancy vehicle lanes or auxiliary lanes (such as truck climbing lanes).

In determining what portion of a project is eligible for IM funding and what portion is capacity expansion (and, therefore, not eligible for IM funds), the basic purpose of the project should be considered. If the project is a combination of preservation and capacity expansion, the cost should be split with 3R items eligible for IM funding and capacity expansion items eligible for other funds. In determining the split, it may be helpful to visualize the project without the capacity expansion work (added lanes, bridge widening or extension for example) and allow IM funding for all necessary 3R items.

Section 1009(e)(4) amends 23 U.S.C. 119(e) to allow IM funding for preventative maintenance activities, which a State can demonstrate through its pavement management system, are a cost-effective means of extending Interstate pavement life. Preventative maintenance includes activities such as sealing joints and cracks, patching concrete pavement, shoulder repair, and restoration of drainage systems which are found to be cost-effective projects resulting in extending the service life of pavements.

This provision has been extended administratively to allow IM funding for other preventative maintenance activities. Examples may include structure work such as crack sealing, joint repair, seismic retrofit, scour countermeasures, and painting of steel members which are cost-effective in extending the service life of the structure.

Toll Roads, Bridges and Tunnels - Section 1012

Section 1012(d) provides that existing toll agreements entered into under Section 119(e) or 129 of Title 23 prior to and in effect on the date of enactment of the 1991 ISTEA, shall continue in effect. All new agreements must be executed in accordance with the provisions of the 1991 ISTEA. Guidance on the use of Federal-aid funds on toll roads has been provided by Mr. Kane's memorandum of March 12, 1992.

Discretionary Funds

There is no provision for set aside of funds from the IM program for discretionary purposes. Also there is no provision for reallocation of apportioned IM funds which lapse at the end of the availability period.

Section 1020 does provide for a continuation of the I-4R discretionary fund program that is separate and distinct from the IM program, The source of the I-4R discretionary funds is an annual set aside from National Highway System (NHS) funds. These I-4R discretionary funds may be used for IM-type projects or for other improvements on the Interstate including projects to provide additional Interstate capacity. A memorandum was issued on December 20, 1991, which outlined procedures for applying for FY 1992 I-4R discretionary funds. A similar memorandum will be issued annually.

Transferability - Section 1009

Section 1009(e)(S)(D) and (E) modifies 23 U.S.C. 119(f) to allow a State to unconditionally transfer an amount not to exceed 20 percent of its IM apportionment to its apportionments under 23 U.S.C. 104(b)(l) for the NHS, *or* 23 U.S.C. 104(b)(3) for the Surface Transportation Program (STP).

Section 1009(b) further amends 23 U.S.C. 119(f) to allow a State to transfer an amount in excess of the 20 percent unconditional IM fund transfer, if the State certifies to the Secretary that (1) the sums to be transferred are in excess of its needs for resurfacing, restoration or rehabilitating its Interstate System routes and (2) the State is adequately maintaining the Interstate System, and if the Secretary accepts the certification.

State requests to transfer IM funds should be submitted to the Division Administrator and may be approved by the Regional Federal Highway Administrator. Funds transferred into the STP will be transferred into the State Flexible Appropriation Code 33D.

Adequate Maintenance of the Interstate System

Requirements for the State to certify that it is adequately maintaining the Interstate System and that the Secretary develop criteria for determining what constitutes "adequate maintenance" were added by Section 1009(c)(2).

Ye anticipate that formal rulemaking may be necessary to allow input from the States in the development of definitive guidance on what constitutes adequate maintenance. Therefore, for the purpose of evaluating State requests to transfer IM funds, in excess of the 20 percent unconditional amount, and until such time as these criteria are established, the guidance contained in the Federal-Aid Policy Guide, CFR 635E and its supplement (old FHPM 6-4-3-1) should be used for determining whether the State is adequately maintaining the Interstate System.

Hadquarters Contacts

This guidance will be updated in the future if further clarifications are found necessary. Questions about what constitutes adequate maintenance of the Interstate System should be directed to the Construction and Maintenance Oivision (HNG-21). Pavement management systems are coordinated by the Pavement Division (HNG-41). Other questions about the IM program should be directed to the Interstate and Program Support Branch (HNG-13).

Anthony R. Kane

Memorandum

U.S. Department of Transportation
Federal Highway Administration

Subject: INFORMATION: Preventive Maintenance

Date: JUL 27 1992

From: Associate Administrator for Program Development

Reply to Attn of: HNG-10

To: Regional Federal Highway Administrators
Federal Lands Highway Program Administrator

Section 119 of Title 23, United States Code, was amended by the Intermodal Surface Transportation Efficiency Act of 1991 to provide specific Federal-aid fund eligibility for preventive maintenance on Interstate highways.

We consider preventive maintenance to include roadway activities such as joint repair, pavement patching, shoulder repair, and restoration of drainage systems, and bridge activities such as crack sealing, joint repair, seismic retrofit, scour countermeasures, and painting., Such work is eligible for Federal-aid participation where the work is determined to be cost-effective for preserving the pavement and bridge structure and extending the pavement and bridge life to at least achieve the design life of the facility.

Due to the nature of preventive maintenance type work, the Division Administrator may approve a request to advance this type of project on Interstate highways without including safety or geometric enhancements, but with the understanding that appropriate safety and geometric enhancements will be an integral part of future 3R/4R projects. This approach may also be applied to minor work the Division Administrator considers eligible for federal-aid funding on other Federal-aid highways. Preventive maintenance or minor work items shall not degrade any existing safety or geometric aspects of the facility.

Anthony R. Kane

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: INFORMATION: Interstate Maintenance Program

Date: June 14, 1993

From: Executive Director

Reply to Attn of: HNG-21

To: Regional Federal Highway Administrators
Division Administrators
Federal Lands Highway Program Administrator

Over the last decade, the State highway agencies have carried out necessary resurfacing, restoration, rehabilitation and reconstruction (4R) of Interstate highways in • ccordance.with the provisions of 23 U.S.C. 119 using funds apportioned under 23 U.S.C. 104(b)(S)(B). Since there was no differentiation in eligibility or pro rata funding for the various classes of work, there was not a need to develop strict definitions for determining whether the proposed work was resurfacing, restoration, rehabilitation or reconstruction. General definitions for pavement reconstruction and pavement rehabilitation (3R) are included in the 'Pavement Policy' (23 CFR 626) which was established in 1988.

Currently, some questions pertaining to the definitions for rehabilitation and reconstruction have been raised since Section 1009(e) of the ISTEA of 1991 generaily eliminated reconstruction on the Interstate System from eligibility under 23 U.S.C. 119, Interstate Maintenance (IM) Program. As revised, this section promotes maintenance of the Interstate System through approval of projects for resurfacing, restoration and rehabilitation, and through preventive maintenance activities.

Preventive maintenance includes restoration or rehabilitaticr of specific elements of a highway facility when it can be demonstrated that such activities are a cost-effective means of extending the pavement life. The list of specific work elements which are generally accepted as extending the service life of pavements and bridges is extensive. In general, any work which provides additional pavement structural capacity (general overlays or replacement of portions of the pavement structure), or prevents the intrusion of water into the pavement or pavement base (seal- coats, joint seals, crack seals, overlays), or provides for removal of water that is in the pavement or pavement base (underdrains, restoration of drainage systems), restores pavement rideabilfty (profiling, milling), or prevents the deterioration of bridges (cleaning and painting, seismic retrofit, scour countermeasures, deck rehabilitation or repair, deck drain cleaning) are considered to be work which extends the service life of the highway, These typical preventive maintenance work items are not intended to be all inclusive but are rather a limited list of examples. The changes made by Section 1009(e) of the ISTEA of 1991 allow considerable flexibility in determining, based on good engineering analysis, the most cost-effective method of extending the service life of the existing Interstate pavements and bridges.

Each of the States either have, or are in the process of developing pavement, bridge and other management systems in response to the ISTEA of 1991 and previous FHWA policies. One of the purposes of a pavement management system is to identify cost-effective strategies for proposed pavement work. In some cases, the most cost-effective' pavement strategy may be removal and replacement of all or part of a badly deteriorated pavement structure. However, if a removal and replacement strategy is considered ineligible for IM funding, a less cost-effective strategy may be selected by the State based only on the class of available funding. Forcing any particular strategy based primarily on availability of funds would not provide the public with the best use of Federal-aid funds. Therefore, in order'to provide the States with necessary flexibility and still meet the intent of the revised 23 U.S.C. 119, pavement work which is identified by the State's pavement management system as being cost-effective, including removal and replacement strategies, where no additional capacity is provided is eligible as an IM Program funded project.

Reconstruction on the Interstate System may still be approved: however, unless the proposed work meets the eligibility requirements' of 23 U.S.C. 119(c), such work must use funds other than those apportioned under 23 U.S.C. 1Ø4(b)(5)(B).

Mr. Anthony R. Kane's Hay 21, 1992, memorandum on '1991 Intermodal Surface Transportation Efficiency Act (ISTEA) Implementation Interstate Maintenance Program" listed, as examples, several types of improvements which were not eligible for IM funding. The example concerning "new ramps" has created some confusion. As a result, further clarification is necessary.

After reviewing the legislation,. we have determined that the addition of new ramps at existing interchanges is properly a part of "interchange reconstruction" and does not constitute added capacity under 23 U.S.C. 119(g). Eligible new ramps may include those associated with reconstruction of existing interchanges necessitated by traffic growth or operational problems. Examples might include the addition of one or more loops to an existing diamond interchange, the addition of a directional ramp to relieve Interstate traffic congestion, or the addition of a ramp or ramps to provide a missing traffic movement. These examples are -also not intended to be all inclusive. In general, new ramps associated with the reconstruction of an existing interchange are eligible for IM funding and conversely, new ramps on an Interstate route where there is presently no existing interchange art not eligible for IM funding.

In addition to these comments and guidance concerning pavement and interchange eligibility; any proposals for Itl funded projects should include considerations for safety or geometric enhancements in accordance with Mr. Kane's July 27, 1992, memorandum on "Preventive Maintenance."

E. Dean Carlson

McTrans

CATALOG

McTrans [Center for Microcomputers in Transportation), is a software distribution and user support center, originally established by the Federal Highway Administration (FHWA), and now supported by the Federal Transit Administration (FTA). The McTrans Center provides support to microcomputer users through technical ossistonca of the software it distributes.

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Carson City PMS

The Carson City Pavement Management System was developed under an FHWA Rural Technical Assistance Program (RTAP) project.

Road inventory data include street name, segment limits and location, subgrade strengths, lengths, widths and surrounding land uses. Structural information includes presence of curb and gutter, shoulder width, surface and base type, thickness and deflection. The condition survey includes information on ride quality, alligator cracking, ravelling and longitudinal plus traverse cracking as the recorded forms of distress; and acceptable, tolerable and unacceptable listed as the three degrees of severity. The total quantity of each distress and severity combination is recorded for each street segment and deduct values assigned. Traffic survey information includes volumes and classification.

The type and extent of distress determine the rehabilitation strategy alternative. The ride quality, alligator cracking and status of sudace ravelling are checked. Then, depending on the traffic index (a measure of truck volume and weights), a maintenance and rehabilitation treatment is recommended. Priorities are assigned based on a cost-benefit ratio determined as a function of cost-per-vehicle-mile. Cost estimates are then applied and listed with the expected life cycle before new treatments are required.

LOS: 3 (from FHWA)

Operating System: IBM PC/MS-DOS 2.1+ (384K and Hard Disk)

Supporting Software: dBASE III+

Product#	Description	Price
CCPMS	Canon City PMS. 7/89	$50
CCPMS.D	Documentation	$10

ELSYM 5

ELSYM 5 is a computerized procedure which models a three-dimensional idealized elastic layered pavement system. It computes the various component stresses, smins, and displacements along with principal values at locations specified by the user, within the layered pavement. This program was developed for the Federal Highway Administration.

LOS: 3 (from FHWA)

Operating System: IBM PC/MS-DOS 2.1+

Product#	Description	Price
ELSYM	ELSYM5, 12/86	$40
ELSYM.D	Documentation	$5

EXPEAR

EXPEAR (EXpert system for Pavements Evaluation And Rehabilitation) is a comprehensive computerized system to assist engineers in evaluating concrete highway pavements, developing feasible rehabilitation alternatives. and predicting the performance and cost ● ffectiveness of the alternatives. In its current state of development it is considered an excellent training tool. Some modifications would be required to make this program suitable for routine use.

A computer program has been developed for each of the three pavement types: jointed Plain Concrete Pavement (JPCP), Jointed Reinforced Concrete Pavements (JRCP), and Continuously Reinforced Concrete Pavement (CRCP). The current version is EXPEAR 1.4 which possesses the capability to do life-cycle cost analysis and to delay rehabilitation up to five years.

EXPEAR was developed by the University of Illinois at Urbana-Champaign under FHWA administrative funded or Highway Planning and Research funded contracts. Further work to enhance the capabilities of EXPEAR is proposed. A hard disk is recommended both for speed of execution and storage of data files.

EXPEAR comes from Kathleen T. Hall of the University of Illinois. A supplemental document describing the Concrete Pavement Evaluation and Rehabilitation System is also available.

LOS: 3

dperating System: IBM PC/MS-DOS 3.0+

Product#	Description	Price
EXPEAR	EXPEAR, Ver.l.4	$45
EXPEAR.D	Documentation	$20
EXPEAR.DS	Supplemental Document	$25

HDM-III and HDM-PC

HDM-III and HDM-PC (Highway Design and Maintenance Standards Model) is designed to make comparative cost estimates and economic evaluations of different construction and maintenance options, including different time stag ing strategies, either for a given road section or an entire network. The concept can simply be outlined as: determining costs, adding the set of costs over time and comparing the total cost streams for various maintenance and construction alternatives.

HD-PC includes the core HDM-III model, a facility to input data, a mechanism to use the outputs with Lotus l-Z-3, and a constrained version of the Expenditure Budgeting Model (EBM). If HDM is used with the EBM, it is capable of comparing options under year-to-year budget constraints.

The basic data requirements are the network description, construction options, maintenance standards and unit costs, vehicle characteristics and unit costs, traffic volumes and projections, exogenous benefits and costs, and analysis period and discount rates. The program is distributed exclusively by Mc Trans under license from the World Bank in Washington, DC.

The HDM-PC comes in two versions: 1) fully supported, which includes free technical assistance and updates and 2) unsupported, which has no support services. Both include the HDM-PC User's Manual and the EBM. The EBM may also be purchased separately (PC only). The mainframe version is only available as fully sup ported. The main HDM-III documentation (HDM.DV1 and .DV2 below), which describe the model in detail, must be purchased separately.

A French version of HDM III is available from PENDC of Paris or through McTrans. Call for details.

LOS: 1 (Copyright 1988, the World Bank)

Operating System: IBM PC/MS-DOS 2.2+ WOK and Hard Disk) and Mainframe

Product#	Description	Price
HDM	Fully supported HDM-PC, Ver.2.0 (incl. EBM. User's Manual, Volumes 1.2 and HDM Manager)	$400
EBM	Fully supported version Of EBM (incl. User's Manual)	$60
HDM.UPG	Upgrade to supported	$300
HDM.UN	Unsupported HDM-PC (incl. EBM and User's Manual)	$100
EBM.UN	Unsupported version of EBM (incl. User's Manual)	530
HDM.D	Extra copies of HDM-PC User's Manual	$15
HDM.DV1	HDM model documentation Vol. 1: Description of HDM-III	$20
HDM.DV2	HDM model documentation Vol. 2: User's Manual for HDM-III	$25

HDM Manager

HDM Manager is a user-friendly shell environment for specific customized applications of HDM-III. It stores the input data in an efficient manner, creates all the required HDM-III input files, runs the HDM-III program, collects the results and presents the results in a practical way. It provides a simple but powerful package for learning and using the major concepts of HDM-III.

HDM Manager is designed to be used with the full HDM-III package and documentation. which must be obtained separately. HDM Manager comes from the World Bank and is included with the fully-supported HDM-III.

LOS: 3 (Copyright 1993, The World Bank)

Operating System: IBM PC/MS-DOS 3.1+

Product#	Description	Price
HDM.MGR	HDM Manager, Ver.2.0	$15

ILLI-BACK

ILLI-BACK is a closed-form backcalculation procedure for rigid pavements. It is a computerized adaptation of a rigorous, theoretically sound and efficient backcalculation procedure, applicable to two-layer, rigid pavement systems. This method simplifies considerably the effort required in interpreting nondestructive testing (NDT) data. A unique feature of this approach is that in addition to yielding the required backcalculated parameters. it also allows an evaluation of, the degree to which the in situ system behaves as idealized by theory, and provides an indication of possible equipment shortcomings when these arise in the field.

The ILLI-BACK backcalculation procedure considers a two-layer system, consisting of a rigid pavement slab resting on an elastic solid (ES) or a dense liquid (DL) foundation. The backcalculation process requires four sensor deflections and utilizes the concept for determining the Area of the deflecting basin.

When ILLI-BACK is executed on a personal computer, execution time per deflection basin permits the interpretation of a vast amount of NDT data in a very reasonable time. The method makes it feasible for the first time to have a practical backcalculation procedure attached to the testing device in the field, providing instant checks on the accuracy of the deflection results generated, while there is still time and opportunity for remedial action. The program supports English and Metric units and runs interactively or in batch mode and is distributed in Copy-Protected format.

LOS: 7 (Copyright 1988, **A.M. Ioannides)**

Operating System: IBM PC/MS-DOS 2.1+ and math coprocessor

Product#	Description	Price
ILBACK	ILLI-BACK, Ver.2.0	$225

ILLI-PAVE Algorithms

ILLI-PAVE Algorithms is a program based on a set of algorithms that were assembled from ILLI-PAVE, a very large complex finite element program. The algorithms are contained in the program called ILLIALGR in the form **of a** series of spreadsheets selected from the menus. ILLI-PAVE Algorithms can be used for preliminary design and analysis of flexible pavements. This program was developed for the Federal Highway Administration.

LOS: 3 (from **FHWA)**

Operating System: IBM PUMS-DOS 2.1+

Product#	Description	Price
ILLI	ILLI-PAVE, 12/86	$40
ILLI.D	**Documentation**	$5

JCP-1

JCP-1 (Jointed Concrete Pavement) determines the serviceability and fatigue data for use in rigid pavement design. The design process is an iterative process in which a designer specifies trial structural designs, determines the required inputs, executes the program, analyzes the resulting fatigue and serviceability **data,** modifies the **design,** and repeats the procedure. The program will analyze any number of slab thicknesses and provide outputs for each thickness, while holding all other inputs constant.

LOS: 3 (from **FHWA)**

Operating System: IBM PUMS-DOS 2.0+

Product#	Description	Price
JCP	Jointed Concrete Pavement-l, 12/86	$45
JCP.D	Documentation	$5

Long Beach PMS

The Long Beach Pavement Management System was also developed under the FHWA Rural Technical Assistance Program (RTAP) project.

The system uses data files for physical information on the sections to be-included in the analysis; pavement survey data detailing the condition of the surface; and information on the scoring, treatment and **cost estimates** for each road segment. Traffic **data are incorporated** into the analysis in the form of a Traffic Index based on ESAL's. An evaluation system is utilized which rates the sections from the pavement surveys and applies a decision tree to determine initial proposed treatments and their estimated costs. LBPMS analyzes both flexible (asphalt concrete) and rigid (Portland cement concrete) pavement types and produces several intermediate and final reports.

LOS: 3 (From **FHWA)**

Operating System: IBM PC/MS-DOS 2.1+ (384K and Hard **Disk)**

Supporting Software: dBASE III+

Product#	Description	Price
LBPMS	**Long Beach PMS, 61139**	$40
LBPMS.D	**Documentation**	$10

MAPCON

MAPCON (Methods for Analyzing Pavement CONdition data) is a comprehensive, but user friendly package for pavement safety, roughness, **structural** capacity and surface condition analysis. MAPCON includes **ELSYMS** and the California FPMS and RPMS (which also are distributed separately) and others. MAPCON provides "paths" to **all the individual programs,** enabling the user to better analyze the pavement conditions, which can then be made part **of a pavement** management system.

MAPCON was developed by Pennsylvania State University and ARE, Inc., under contract to FHWA. A hard disk is highly **desirable, but** not required.

LOS: 3 (from FHWA)

Operating System: IBM PC/MS-DOS 2.0+ (512K)

Product#	Description	Price
MAPCON	MAPCON, 4/87	$100
MAPCON.D	Documentation	$65

MIX

MIX is a menu driven, BASIC program which calculates the specific gravities of aggregates for the design of the asphalt mix and the proportions of each aggregate in the mix. The program is based on the methodology described in the MS-2 Report published by the Asphalt I stitute. No formal documentation is availabl

LOS: 5 (from University of Puerto Rico)

Operating System: IBM PC/MS-DOS 2.0+

Supporting Software: BASIC

Product#	Description	P
MIX	MIX, 1/80	

MODULUS and PASELS

MODULUS and PASELS are two programs assess the current condition of the moduli o various structural Layers **of** existing asphalt pavement. The moduli values **are** often obtained through nondestructive testing with use of falling weight deflectometers. The h volume data collection capabilities of modt nondestructive testing equipment require a analysis method which is capable of rapid backcalculation of pavement layer moduli production mode of data reduction. A layer elastic method, MODULUS, was develope microcomputer use which is **very fast** in op tion and provides consistently reliable rest Random errors in the measurements and sy tematic errors in the backcalculation proct may be reduced-the former by repeating th measurements and the latter by using a mi computer expert system, **PASELS,** to provi consistently acceptable layer moduli value

These programs were developed under a tional Cooperative Highway Research Prc gram project, the results of which **are** pub lished as **NCHRP Report 327, "Determini** Asphaltic Concrete Pavement Structural F erties by Nondestructive Testing." This r which contains user's manuals for both p grams, may be obtained through the Tran tation Research Board, Washington, D.C.

LOS: 3

Operating System: IBM PC/MS-DOS 2.0+

Product#	Description
MODUL	MODULUS, Ver.4.0
PASEL	PASELS, Ver.1.0

NULOAD

NULOAW is a computerized procedure th **evaluates** the effect of legal load limit cha on the (set of 12) life cycle costs of flexibl rigid, **and/or composite** pavements. Data i are interactively input through NULDIN, user-friendly processor for NULOAD. Co erable input data is required.

LOS: 3 (from FHWA)

Operating System: IBM PUMS-DOS 2.0+

Product#	Description
NULOAD	**NULOAD, 12/86**
NULOAD.D	Documentation

PAVECHEK

Pavechek is a software package for designing interlocking concrete pavements. The structural design of flexible interlocking concrete pavements can be accomplished quickly on this menu-driven, PC computer based program. Pavement cross section designs can be generated for both new or overlay interlocking concrete pavements with unbound or bound base materials. Various levels of sophistication can be used in the program depending on the level of detail of input data available. The design rationale IS based on the widely used 1986 AASHTO "Guide for the Design of Pavement Structures".

LOS: 7

Operating System: IBM PC/MS-DOS 2.1+ (Graphics)

Product#	Description	Price
PAVECHEK	Pavechek, Ver.1.0	$55

Pavement Management Forecasting Model .

Pavement Management Forecasting Model (PMF) is a Lotus l-2-3 template for use in planning roadway maintenance and strategies. It runs in a Lotus, Release 2 environment and is completely menu driven. Data on road maintenance and construction unit costs, pavemtnt deterioration rates, future funding estimates and current road conditions are required. Based upon three repair strategies, output is generated in tabular summaries and graphic plots. It allows changes at any level to iterate to desired results.

Agencies responsible for roadway maintenance related funding decisions will find it useful to compare various alternatives. The Lotus design is included in the appendix for users who might modify the algorithms to customized ● P-plications. PMF was donated by Mr. William Massicott of tht Metropolitan Area Planning Council, Boston.

LOS: 3

Optrating Systtm: IBM PC/MS-DOS 2.0+

Supporting Software: Lotus I-Z-3

Product #	Description	Price
PMF	PMF, Ver. 1.0	$40
PMF.D	Documentation	$15

Pavement Management System

Pavemtnt Management System (PMS) is a decision support tool ustd to assist managtmtnt responsiblt for allocating pavemtnt maintenance resources. In a simple view, PMS is a process where information about the pavemtnt system is collected, stored, analyzed and rtporttd.

This third generation, Version 3.0, combines a life cycle approach to pavement maintenance with a user-friendly, mouse or ktyboard driven graphical user interface. This standard system includes five modules for analyzing inventory. history. pavement condition, cost and budget. and a knowledge-based ranking system. It uses a maintenance priority ranking system based upon the data collected and stored in the other four modules. In addition, the system's modular design allows the integration with other software to provide enhanced graphical reports and system performance feedback.

LOS: 7 (Copyright 1992, Resource International, Inc.)

Operation System:IBM PC/MS-DOS 3.0+

Product#	Description	Price
PMS	PMS	5695
PMS.GIS	PMS GIS version	$2,500

PMSPro

PMSPro is a pavement management program written in the Microsoft Windows environment using FoxPro for Windows. The program allows the user to completely customize the program by defining decision trees. rehabilitation strategies, deterioration curves. deduct curves. and costs for different pavement types, functional classes, and traffic classes. PMSPro also contains other methods of calculating condition scores such as: WADOT PSC, FAA PCI, PAVER PCI.

PMSPro evaluates a street network both at tht project level and tht network level. At the Project Level, condition scorn are ustd to prioritize strttts. Decision trees evaluate the type and amount of distress to select an appropriate rehabilitation strategy. PMSPro can evaluate all street segments or only those that have changed since tht last analysis.

A complete cost accounting package allows costs to be adjusted according to the type and amount of distress as well as othtr costs such as flagging and ● nginteting.

At tht Network Level, a simplifitd decision process uses future calculated condition scores to select an ● ppropriatt rehabilitation strategy and cost The analysis ptriod can range from 5 to 80 years. Evaluate by functional class or traffic class. Carry unspent funds forward. Prioritize by Wont Fint or Last.

PMSPro also can handle condition surveys or ditches, sidewalks, street signs and other street accessories. A maintenance modult allows tht tracking of past maintenance and costs.

Compatible with most CIS programs. including MapInfo from MapInfo, Inc. A GIS program can display pavtmtnt condition. recommended rehabilitation strategies, pavement types, sign inventory, etc. by connecting the databases to a map.

LOS: 7 (Copyright 1992©1994, Pavement Engineers, Inc.)

Operating Software: IBM PC'MS-DOS 3.0+

Product #	Description	Price
PMSPRO	PMSPRO Pavement Management Program Ver. 5.2	51.000

Road Manager™

The Road Manager™ is a modular roadway management system. Its unique features are the ability to include ALL roadway features in the evaluation of a road section, a modular design, user defined parameters allowing extensive customization to fit local conditions and policies, and a modem software design using light bar menus, a complete help system and pick lists for easy data entry.

The General Roadway module serves as the "control center" for all other modules, recording road lengths, widths, classifications, etc., as well as overall condition indices for eight different types of roadway features. The General Roadway module can also be used as a stand alone system. suitable for "windshield survey" evaluation of a road network. *The General* Roadway module IS *required* for *all other modules.*

The Asphalt Pavement, Roadway Drainage and Roadway Utility modules allow the detailed inventory and evaluation of roadway distresses, drainage needs and utility related features. These modules include a user definable decision table that determines recommended repairs or maintenance. All calculations related to determining a condition index, recommended repairs and estimated costs can be modified by the user.

The Improvement Plan module uses information generated in the Asphalt Pavement, Roadway Drainage and Roadway Utility modules lo develop lists of recommended improvements as well as required budgets to attain a given network condition level. The computer-generrttd plan for impmvtmenb can be oveniddtn by the user. The estimated dettriontion curves used by the system in projecting future pavement and utility patch condition can also be modified.

The Repair History module serves as an electronic file cabinet, recording all work performed on a road section as it is completed. Tht Street Diagram module graphically displays and prints all Drainage and Utility features that have been inventoried through their respective modules.

LOS: 7 (Copyright 1989, The Info Center, Inc.)

Operating System: IBM PC/MS-DOS 3.0+ (640K and Hard Disk)

Product#	Description	Price
RMRD	General Roadway, Ver. 1.51	$495
RMAS	Asphalt Pavement, Ver. 1.51	$995
RMCR	Gravel Road, Ver. 1.51	$495