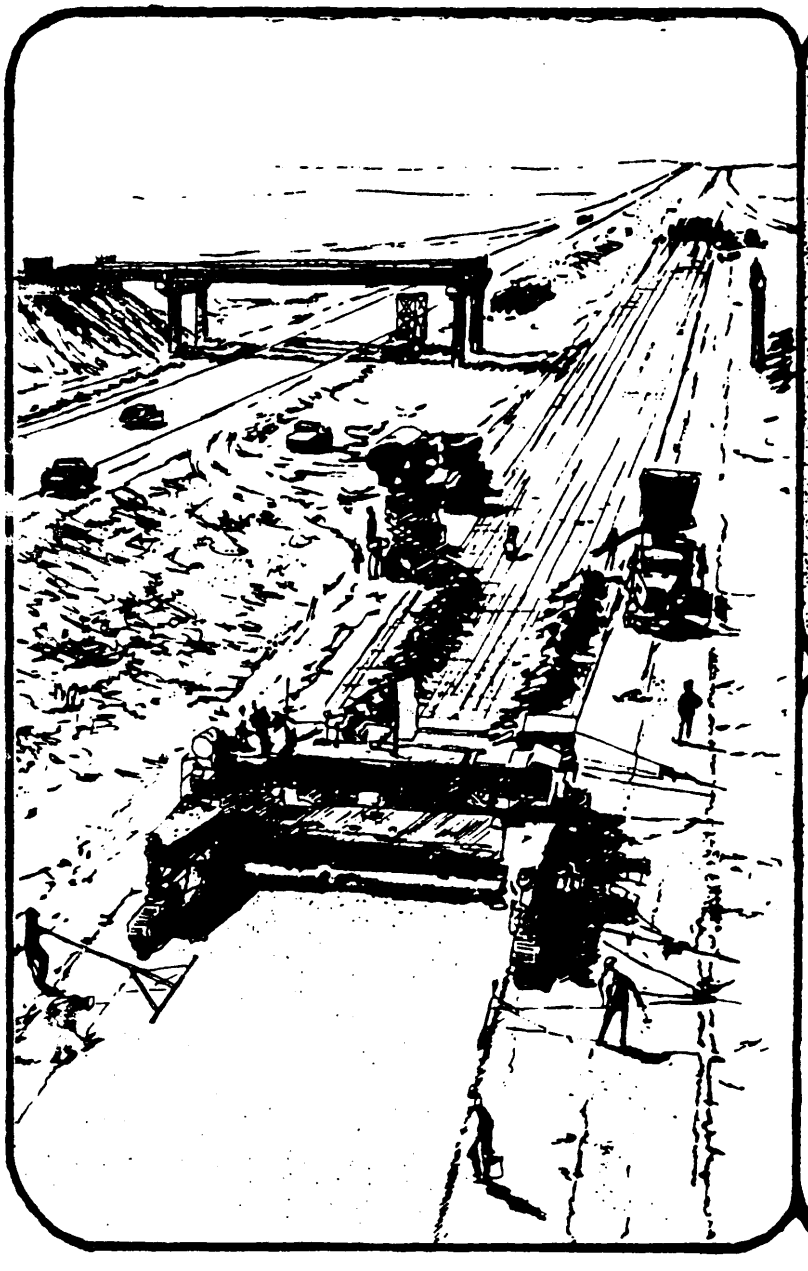
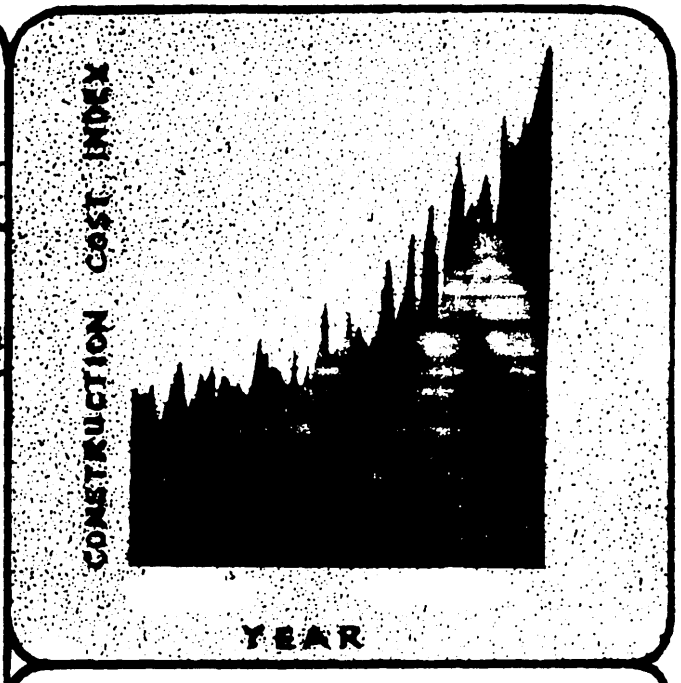
ENGINEERING ECONOMY AND ENERGY CONSIDERATIONS

COSTS ASSOCIATED WITH PAVEMENT CONSTRUCTION, REHABILITATION AND MAINTENANCE

RESEARCH REPORT 214-18

AUGUST 1980





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"ENGINEERING, ECONOMY AND ENERGY CONSIDERATIONS IN DESIGN, CONSTRUCTION AND MATERIALS"

TEXAS STATE DEPARTMENT
OF HIGHWAYS
AND PUBLIC TRANSPORTATION

AND

TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

TASK FORCE ON ENGINEERING, ECONOMY AND ENERGY CONSIDERATIONS

Larry G. Walker, Task Force Chairman and Materials and Tests Engineer

Charles H. Hughes, Sr., Study Contact Representative and Assistant Materials and Tests Engineer

A.H. Pearson, Jr., Assistant State Engineer-Director

Wayne Henneberger, Bridge Engineer

Robert L. Lewis, Chief Engineer, Highway Design

Byron C. Blaschke, Chief Engineer, Maintenance Operations

J.R. Stone, District Engineer

William V. Ward, Urban Project Engineer-Manager

Phillip L. Wilson, State Planning Engineer

Franklin C. Young, District Engineer

Theodore E. Ziller, Construction Engineer

COSTS ASSOCIATED WITH PAVEMENT CONSTRUCTION, REHABILITATION AND MAINTENANCE

by

J. A. Epps and F. N. Finn

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INTRODUCTION

The engineer responsible for the rehabilitation of a road network is responsible for allocating his monetary resources in an optimum manner. Thus, he must decide on what portion of the roadway network he intends to perform rehabilitation as well as what specific rehabilitation action is most appropriate for a particular roadway segment. Project feasibility is determined at the network level by comparing the needs of the entire roadway system. Selection of a specific rehabilitation alternative for a given project requires that a variety of alternatives be considered from an economic standpoint. The economic tools used by the engineer to make those "network" and "project" decisions are nearly the same with the amount of detailed information required as the major difference.

This paper presents techniques suitable for selection of a rehabilitation strategy for a particular project. The techniques available make use of the principles of engineering economy and methods of economic evaluation. Thus, cost information is required together with information concerning the life of various rehabilitation alternatives. Cost information must be projected for the life of the project and techniques utilized to reduce these costs at various ages after reconstruction to some "common denominator". Hence, the term "life cycle analysis" is often utilized.

Information defining component costs of various construction and rehabilitation alternatives has also been included. These data can be used for sensitivity analyses. For example, if the price of asphalt cement is increased 50 percent, what will be the impact on the cost of asphalt concrete, chip seal coats and asphalt-rubber chip seals.

Indexes have been included in the paper in order that estimates of current costs can be made with the data enclosed. These indexes are continually updated by the Federal Highway Administration and are readily available.

COSTS ASSOCIATION WITH PAVEMENT REHABILITATION

The initial and recurring costs that an agency may consider in the economic evaluation of alternative rehabilitation strategies have been defined in Reference 1 and include the following:

1. Agency costs
    a. Initial capital costs of rehabilitation
    b. Future capital costs of reconstruction or rehabilitation (overlays, seal coats, etc.)
    c. Maintenance costs, recurring throughout the design period
    d. Salvage return or residual value at the end of the design period
    e. Engineering and administration
    f. Costs of investments
2. User costs
    a. Travel time
    b. Vehicle operation
    c. Accidents
    d. Discomfort
    e. Time delay and extra vehicle operating costs during resurfacing or major maintenance
3. Nonuser costs

Certainly all of these costs should be included if a detailed economic analysis is desired. However, definition of many of these costs is difficult while other costs do not significantly affect the analysis of alternatives for a given roadway segment. For the sake of simplicity the method of analysis suggested for use in these guidelines will consider only the following costs:

1. Initial capital costs of rehabilitation,
2. Future capital costs of reconstruction or rehabilitation,
3. Maintenance costs and
4. Salvage value.

It is suggested, however, that certain user costs such as time delay costs during rehabilitation be considered on high traffic volume facilities. The reader is directed to References 1 and 2 for additional detail.

SELECTION OF DISCOUNT RATE (INTEREST RATE)

The discount rate (interest rate) (rate of return) is utilized to reduce future expected costs for projects to present day terms for economic comparison purposes. The value selected for discount rate deserves careful attention by the engineer. The rate selected is normally between 4 to 10 percent while the actual value selected should be based upon consideration of the following:

1. Interest rate currently charged to borrow capital
2. Rate of return expected of private investments
3. Rate of return expected of public works investments
4. Risks and uncertainties associated with investments

5. Short term and long term inflation rates

It should be noted that rehabilitation alternatives with large initial costs and low maintenance or user costs are favored by low interest rates. Conversely, high interest rates favor strategies that combine low initial costs with high maintenance and user costs.

A discount rate of 8 percent has been utilized together with a 20-year analysis period for examples in these guidelines. Present worth factors and capital recovery factors for discount rates of 6, 7, and 8 percent are shown in Table 1. Values for other discount rates can be found in Reference 2 or text books on engineering economy. Both present worth and the uniform annual cost method are illustrated below. Costs are estimated in terms of dollars per square yard; however, costs in terms of dollars per lane-mile is also a convenient unit.

COST DATA

Data are included in this paper which define costs associated with pavement construction, reconstruction and maintenance operations. These costs are intended to be representative only. If costs for these operations are available from local agencies' historical records, they should be substituted appropriately.

Construction Costs

Costs of common pavement construction operations are shown in Table 2. These costs are considered representative of average in-place costs in the United States. Costs are based on pavement layers in the range of 4 to 8 inches (102 to 203 mm) for untreated base and stabilized layers. Asphalt concrete costs are typical of 1.5 to 3 inch (38 to 97 mm) lifts

while portland cement concrete costs are typical for pavements 8 to 10 inches (203 to 254 mm) in thickness.

Rehabilitation and Pavement Recylcing Costs

Costs associated with selected rehabilitation and pavement recycling operation costs are shown in Tables 3, 4 and 5. The common rehabilitation activities of asphalt concrete overlays, chip seal costs, etc. can be found in Table 3. Recycling costs are shown in Tables 4 and 5.

Maintenance Costs

Costs assoicated with flexible pavement maintenance operations are shown in Table 6 and with rigid pavement maintenance operations in Table 7. Costs were obtained from the states of Arizona, California, Nevada, and North Dakota and are representative of costs in 1977.

A general description for each maintenance activity has been prepared and is shown in the tables together with the average, low, and high unit costs for these activities. The reported suggested costs are the author's best estimate of representative unit costs for the stated maintenance activity. The wide range of reported unit costs for this condensed list of activities is due in part to:

1. Different crew sizes utilized in the various states
2. Different equipment requirements for various states
3. Differences in maintenance work activity as defined by various states
4. Variety of traffic conditions under which maintenance is performed
5. Type of facility on which maintenance activities are performed

6. Amount of work performed per lane mile

Maintenance unit cost information has been converted to costs per square yard (square m) of total pavement surface area treated and cost per lane mile (km) (Table 8). In order to develop these costs, assumptions were made as to the thickness and extent of the area treated. Costs associated with maintenance activities of different thicknesses and extent can be calculated from Table 6 and 7.

The summary of information contained in the previous tables is for 10 flexible and 5 rigid pavement maintenance activities. As stated, these costs are based on the data obtained from four states. If the reader has need of determining maintenance costs for activities other than those listed in the tables, it will be necessary to obtain data from a local state, county, or city performing that activity.

The reader is reminded that the maintenance activities described in this report are normally performed on pavements with certain specific types of distress. For example, fog seals and chip seals are popular maintenance or rehabilitation activities that are used to correct raveling flexible pavements. Typical types of flexible pavement distress and maintenance activites associated with maintenance of these types of distress are shown in Table 9.

Example Problem

A nine-mile segment of pavement in West Texas is in need of rehabilitation. The present pavement consists of 4 inches of asphalt concrete and chip seal coats placed over 8 inches of an unstabilized crushed limestone base. The existing pavement has extensive longitudinal and transverse cracks with a limited amount of alligator cracks. Ten

rehabilitation plans are under consideration. These plans are briefly described in Table 10 while costs for the rehabilitation alternatives are shown in Table 11. The anticipated life cycle costs are shown in Table 12.

Plans 1 and 7 have been selected to demonstrate the calculations associated with life-cycle costs. Plan 1 consists of a two inch asphalt concrete overlay with maintenance. Overlays are scheduled on a 7-year cycle. Plan 7 consists of recycling the existing 4 inches of asphalt bound material and a 2-inch overlay of asphalt concrete with maintenance. Subsequent overlays will not be needed during its 20-year life. Tables 13 and 14 show the life cycle costs calculations associated with Plans 1 and 7. Table 15 is a blank calculation sheet. Present worth values for all 10 rehabilitation alternatives on a 20-year life cycle are shown in Table 16. Values are shown for both 0 and 8 percent rates of returns.

COST UPDATING PROCEDURES

As cost information is obtained from various sources at various times, it is necessary to bring these costs to a common time frame. In order to convert cost figures contained in this report to a current date, the cost index method is suggested. The following equation can be used.

$$C_c = C_o \left(\frac{I_c}{I_o} \right)$$

where: C_c = Current estimated cost

C_o = Cost at other time "O"

I_c = Current index number

I_o = Index number at other time "0"

The index number to use depends upon the type of cost being estimated. Four indices are given from which to choose:

1. The ENR Construction Cost Index (3)
2. Bid Price Trends on Federal-Aid Highway Contracts (4)
3. The ENR Equipment Price Index (3)
4. The Cost Trends on Highway Maintenance and Operations (4)

The ENR Construction Cost Index (Table 17) was designed as a general purpose construction cost index to chart basic costs with time. It is a weighted index of constant quantities of structural steel, portland cement, lumber, and common labor, valued at $100 in 1913.

The Bid Price Trends on Federal-Aid Highway Contracts is compiled by the Federal Highway Administration as reported by state transportation agencies (Table 18). The base year for this index is 1967.

The ENR Equipment Price Index (Table 19) is compiled from Bureau of Labor statistics and only the January, 1980, index is given (for a base year of 1967). To use this index subtract 100 from the 1980 index then divide by 13 to obtain an average yearly percent increase in equipment costs or use the percent change listed for the period 1979-1980.

The Cost Trends for Highway Maintenance and Operations (Table 20) are given through 1978 (the latest year available).

FUTURE COST TRENDS

The information contained in Tables 17-20 can be supplemented and used to project future cost trends associated with materials used for construction, rehabilitation and maintenance. Figure 1 and 2 illustrate

the rate of increase of costs since 1967. The rapid increases in costs between 1973 and 1974 were a result of ending the federal price controls and the Arab oil embargo. Highway price moderations during the period 1974 to 1977 were a result of a general decrease in highway construction work (more competition for the same projects) and moderation of the general rate of inflation and crude oil prices.

It is important to realize that considerable regional and local price differences exist throughout the United States. Figure 3 illustrates the differences among the price of asphalt concrete in Texas, Region 6 of the FHWA (Texas, Oklahoma, New Mexico, Arkansas and Louisiana) and the average price for the United States. Potential reasons for these differences are outlined in Reference 6. Three reasons which are responsible for price increases throughout the United States are the price of crude oil, asphalt cement and the cost of transportation. Figure 4 illustrates the price of imported crude oil from 1973 to present. (The United States presently imports about 45 percent of its crude oil.) Figure 5 shows the price increases associated with asphalt cement in Texas. Similar price increases are noted throughout the United States. The present posted price of asphalt cement is about 130 dollars F.O.B. refinery. Transportation cost increases will closely follow the price increases associated with crude oil.

A review of the attached cost trends indicate the following annual rates of inflation for the various items during the period 1977-1979 in the United States.

Item or Index	Annual Rate of Inflation, Percent
Building cost index	8.8
Construction cost index	8.2
Highway bid price index	21.2
Highway maintenance cost index	7.8
Asphalt concrete	18.5
Portland cement concrete	19.7
Excavation	19.8
Mideastern crude oil	13.6
Asphalt cement	21.5
Rail transportation	10.8
Truck transportation (Texas only)	16.3

The expected rate of cost increases for many construction related items in the 1980 to 1981 period are expected to be 20 $\pm$ percent. The expected price increases associated with asphalt cement and No. 2 fuel oil are shown in Figure 8.

CONCLUSIONS AND RECOMMENDATIONS

Cost and cost updating procedures have been presented for a wide range of construction, rehabilitation and maintenance operations. These data together with predictions of service life can be used to predict life cycle costs as demonstrated in the report.

REFERENCES

1. Haas, Ralph and W. R. Hudson, Pavement Management Systems, McGraw-Hill Book Company, 1978.

2. Yoder, E. J. and M. W. Witczak, Principles of Pavement Design, Second Edition, John Wiley and Sons, Inc., 1975.

3. "Engineering News Reocrd", March 20, 1980.

4. "Price Trends for Federal-Aid Highway Construction", U. S. Department of Transportation, Federal Highway Administration, 4th Quarter, 1979.

5. Highway Statistics, U. S. Department of Transportation, Federal Highway Administration, 1978.

6. Epps, J. A. and C. W. Smoot, "Asphalt Concrete Price Escalation" Report 214-15, Texas Transportation Institute, May, 1980.

7. U. S. News and World Report, June 23, 1980.

8. U. S. Department of Labor, Bureau of Labor Statistics.

9. Fehd, C., "Introducing Price Indexes for Railroad Freight", Monthly Labor Review, June, 1975.

10. Texas Railroad Commission, September, 1979.

11. Engineering News Record, December 20, 1979.

Table 1. Present Worth and Capital Recovery Factors.

	Present Worth Factor			Capital Recovery Factor		
	Interest Rate			Interest Rate		
Years	6	7	8	6	7	8
1	0.9434	0.9436	0.9259	1.06000	1.07000	1.08000
2	0.8900	0.8734	0.8573	0.54544	0.55309	0.56077
3	0.8396	0.8173	0.7938	0.37411	0.38105	0.38803
4	0.7921	0.7629	0.7350	0.28859	0.29523	0.30192
5	0.7473	0.7130	0.6806	0.23740	0.24389	0.25046
6	0.7050	0.6663	0.6302	0.20336	0.20980	0.21632
7	0.6651	0.6227	0.5835	0.17914	0.18555	0.19207
8	0.6274	0.5820	0.5403	0.16104	0.16747	0.17401
9	0.5919	0.5439	0.5002	0.14702	0.15349	0.16008
10	0.5584	0.5083	0.4632	0.13587	0.14238	0.14903
11	0.5268	0.4751	0.4289	0.12679	0.13336	0.14008
12	0.4970	0.4440	0.3971	0.11928	0.12590	0.13270
13	0.4688	0.4150	0.3677	0.11296	0.11965	0.12652
14	0.4423	0.3878	0.3405	0.10758	0.11434	0.12130
15	0.4173	0.3624	0.3152	0.10296	0.10979	0.11683
16	0.3936	0.3387	0.2919	0.09895	0.10586	0.11298
17	0.3174	0.3166	0.2703	0.09544	0.10243	0.10963
18	0.3505	0.2959	0.2502	0.09236	0.09941	0.10670
19	0.3305	0.2765	0.2317	0.08962	0.09675	0.10413
20	0.3118	0.2584	0.2145	0.08718	0.09439	0.10185
21	0.2942	0.2415	0.1987	0.08500	0.09229	0.09983
22	0.2775	0.2257	0.1839	0.08305	0.09041	0.09803
23	0.2618	0.2109	0.1703	0.08128	0.08871	0.09642
24	0.2470	0.1971	0.1577	0.07968	0.08719	0.09498
25	0.2330	0.1842	0.1460	0.07823	0.08581	0.09368
26	0.2198	0.1722	0.1352	0.07690	0.08456	0.09251
27	0.2074	0.1609	0.1252	0.07570	0.08343	0.09145
28	0.1956	0.1504	0.1159	0.01459	0.08239	0.09049
29	0.1846	0.1406	0.1073	0.07358	0.08145	0.08962
30	0.1741	0.1314	0.0994	0.07265	0.08059	0.08883

Table 2. Cost of Common Pavement Construction Operations - 1979.

Construction Operation	Representative Costs $ Per Sq. Yard - In.	
	Average	Range
Crushed stone base	0.60	0.30 - 0.75
Gravel base	0.50	0.20 - 0.75
Lime stabilized subgrade	0.30	0.15 - 0.45
Cement stabilized subgrade	0.40	0.20 - 0.50
Cement treated base	1.00	0.60 - 1.40
Asphalt treated base	1.00	0.60 - 1.25
Lime--fly ash--aggregate base	0.90	0.60 - 1.00
Chip seal	0.45	0.20 - 0.55
Asphalt concrete	1.25	0.70 - 1.50
Portland cement concrete	1.65	1.00 - 2.50

$1\ yd^2 = 8.361 \times 10^{-1}\ m^2$

$1\ in. = 2.54 \times 10^{-2}\ m$

Table 3. Cost of Pavement Rehabilitation Operations (1979).

Rehabilitation Operation	Approximate Thickness, Inch	Representative Cost $ per sq. yd.	
		Average	Range
Chip seal coat	1/2	0.45	0.20 - 0.55
Fabric interlayers	1/4	1.10	0.75 - 1.75
Asphalt-rubber interlayer	1/2	1.25	0.90 - 1.50
Open graded friction course	5/8	1.50	1.00 - 2.50
Asphalt concrete (dense graded)	1	1.50	1.00 - 2.50
Asphalt concrete (dense graded)	2	2.60	1.80 - 4.80
Asphalt concrete (dense graded)	3	3.30	2.40 - 6.00

$1\ yd^2 = 8.361 \times 10^{-1}\ m^2$

$1\ in. = 2.54 \times 10^{-2}\ m$

Table 4. Costs of Common Recycling Operations - 1979.

Recycling Operation	Representative Costs $ Per Sq. Yard - In*	
	Average	Range
Heat and Plane Pavement - 3/4 inch depth	0.30	0.15 - 0.60
Heat and Scarify Pavement - 3/4 inch depth	0.50	0.15 - 0.90
Cold Mill Pavement	0.85	0.30 - 1.25
Rip, Pulverize and Compact - Existing Pavement less than 5 inches of Asphalt Concrete	0.25	0.13 - 0.45
Rip, Pulverize, Stabilize and Compact - Existing Pavement less than 5 inches of Asphalt Concrete	0.45	0.20 - 0.50
Rip, Pulverize and Compact - Existing Pavement greater than 5 inches of Asphalt Concrete	0.30	0.15 - 0.50
Rip, Pulverize, Stabilize and Compact - Existing Pavement Greater than 5 inches of Asphalt Concrete	0.50	0.25 - 0.60
Remove and Crush Portland Cement Concrete	0.60	0.30 - 0.90
Remove and Crush Asphalt Concrete	0.40	0.20 - 0.60
Cold Process - Remove, Crush, Place, Compact, Traffic Control - (Cold Process) without Stabilizer	0.50	0.30 - 0.75
Cold Process - Remove, Crush, Mix, Place, Compact, Traffic Control - (Cold Process) with Stabilizer	0.60	0.35 - 0.90
Hot Process - Remove, Crush, Place, Compact, Traffic Control - without Stabilizer	0.75	0.45 - 1.20
Hot Process - Remove, Crush, Mix, Place Compact, Traffic Control - with Stabilizer	0.90	0.50 - 1.25

*Costs are for a square yard inch except where listed.

1 yd. = 8.361×10^{-1} m^2

1 in. = 2.54×10^{-2} m

Table 5. Representative Costs for Pavement Recycling Operations (1979).

Type	Operation	Option or Expected Results		Representative Costs Per Sq. Yd. Average	Range	Assumptions
A. Surface	Heater Planer	Without Additional Aggregate	A1	0.60	0.45 - 1.15	heat, plane, clean-up, haul, traffic control
		With Additional Aggregate	A2	0.55	0.40 - 1.00	spread aggregate, heat, roll, traffic control and clean-up
	Heater Scarify	Heater scarify only	A3	0.60	0.35 - 1.00	heat, scarify, recompact, traffic control (3/4 inch scarification)
		Heater scarify plus thin overlay of aggregate	A4	0.40	1.00 - 1.75	heat, scarify, recompact, add 50 lbs. of asphalt concrete per square yard, compact, traffic control, (3/4 inch scarification)
		Heater scarify plus thick overlay	A5	4.10	3.25 - 5.00	heat, scarify, recompact, add 300 lbs. of asphalt concrete per square yard, compact, traffic control (3/4 inch scarification)
	Surface Milling or Grinding	Surface milling only	A6	0.75	0.45 - 1.50	milling, cleaning, hauling, traffic control. (1 inch removal)
		Surface milling plus thin overlay	A7	3.25	2.50 - 3.75	milling, cleaning, hauling, 200 lbs. of asphalt concrete, traffic control (1 inch removal)
		Surface milling plus thick overlay	A8	5.75	4.70 - 7.20	milling, cleaning, hauling 400 lbs. of asphalt concrete, traffic control (1 inch removal)
B. In-Place	Asphalt Concrete surface less than 4 in.	Minor structural improvement without new binder	B1	3.50	2.75 - 4.25	rip, pulverize and remix to 4 inch depth with 2 inches of asphalt concrete, traffic control

Type	Operation	Option or Expected Results		Representative Costs Per Sq. Yd. Average	Range	Assumptions
B. In-Place	Asphalt Concrete Surface less than 5 in.	Minor structural improvement with new binder	B2	3.00	2.40 - 3.70	rip, pulverize and remix with stabilizer to 4 inches depth with 1 inch of asphalt concrete, traffic control
		Major structural improvement without new binder	B3	6.50	5.10 - 7.90	rip, pulverize and remix to 6 inches depth with 4 inches of asphalt concrete, traffic control
		Major structural improvement with new binder	B4	5.10	4.10 - 6.20	rip, pulverize and remix with stabilizer to 6 inch depth with 2 inches of asphalt concrete, traffic control
	Asphalt Concrete Surface Greater Than 5 in.	Minor structural improvement without new binder	B5	3.75	3.00 - 4.50	rip, pulverize and remix to 4 inch depth with 2 inches of asphalt concrete, traffic control
		Minor structural improvement with new binder	B6	3.25	2.60 - 3.90	rip, pulverize and remix with stabilizer to 4 inch depth with 1 inch of asphalt concrete, traffic control
		Major structural improvement without new binder	B7	6.90	5.50 - 8.25	rip, pulverize and remix to 6 inch depth with 4 inches of asphalt concrete, traffic control
		Major structural improvement with new binder	B8	5.50	4.35 - 6.65	rip, pulverize and remix with stabilizer to 6 inch depth with 2 inches of asphalt concrete, traffic control
C. Central Plant	Cold Mix Process	Minor structural improvement without new binder	C1	4.50	3.60 - 5.40	remove, crush and replace to 4 inch depth with 2 inches of asphalt concrete, traffic control
		Minor structural improvement with new binder	C2	3.75	3.00 - 4.50	remove, crush, mix, and replace to 4 inch depth with 1 inch of asphalt concrete, traffic control

Table 5. Continued

Type	Operation	Option or Expected Result		Representative Costs Per Sq. Yd. Average	Representative Costs Per Sq. Yd. Range	Assumption
	Cold Mix Process	Major structural improvement without new binder	C3	8.00	6.40 - 9.70	remove, crush and replace to 6 inch depth with 4 inches of asphalt concrete, traffic control
		Major structrual improvement with new binder	C4	6.25	5.00 - 7.50	remove, crush, mix and replace to 6 inch depth with 2 inches of asphalt concrete, traffic control
	Hot Mix Process	Minor structural improvement without new binder	C5	4.90	3.90 - 5.90	remove, crush, and replace to 4 inch depth with 1.5 inches of asphalt concrete, traffic control
		Minor structural improvement with new binder	C6	4.10	3.25 - 5.00	remove, crush, mix and replace to 4 inch depth with 1/2 inch of asphalt concrete, traffic control
		Major structural improvement without new binder	C7	8.25	6.60 - 9.90	remove, crush and replace to 6 inch depth with 3 inches of asphalt concrete, traffic control
		Major structural improvement with new binder	C8	6.50	5.25 - 7.75	remove, crush, mix and replace to 6 inch depth with 1 inch of asphalt concrete

Table 6. Unit Cost for Flexible Pavement Maintenance Operations (1977).

Descriptive Title	General Description	State	No.	Reported Avg. Unit Cost, Dollars	Suggest Cost, Dollars			
					Avg.	Low	High	Unit Meas.
Fog Seal - Partial Width	Light application of diluted emulsion or a proprietary material over a partial lane.	ARI	109	0.095/yd^2	.095	.075	.131	yd^2
Fog Seal - Full Width	Light application of diluted emulsion or a proprietary material over a full lane width in a continuous section.	ARI CAL NEV ND	108 01.983 101.06 435	0.069/yd^2 0.06/yd^2 0.06/yd^2 0.11/yd^2	.06	.05	.11	yd^2
Chip Seal - Partial Width	Application of asphalt and cover aggregate to a limited area.	ARI CAL NEV ND	104 01-051 101.05 412	0.36/yd^2 0.41/yd^2 0.23/yd^2 0.26/yd^2	.35	.23	.41	yd^2
Chip Seal - Full Width	Application of asphalt and cover aggregate to a full lane width in a continuous section.	ARI CAL NEV ND	106 01-054 101.09 422	0.18/yd^2 0.24/yd^2 0.23/yd^2 0.21/yd^2	.21	.18	.24	yd^2
Surface Patch-Hand Method	Application of a Premix material to the surface of the pavement by hand method.	ARI CAL NEV	102 01-031 101.02	34.56/yd^3 147.00/yd^3 123.60/yd^3	130.00	60.00	170.00	yd^3
Surface Patch-Machine Method	Application of a Premix material to the surface of the pavement with machine.	ARI CAL CAL CAL CAL NEV ND	102 01-021 01-022 01-023 01-024 101.03 421	34.56/yd^3 52.50/yd^3 43.00/yd^3 28.50/yd^3 40.40/yd^3 27.96/yd^3 22.35/yd^3	28.00	20.00	40.00	yd^3
Digout & Repair Hand Method	Removal and repair of limited areas by use of hand tools.	ARI CAL ND	101 01-034 411	112.29/yd^3 145.00/yd^3 55.34/yd^3	110.00	40.00	160.00	yd^3
Digout & Repair Machine Method	Removal and repair of limited areas by use of mechanized equipment.	ARI CAL NEV	105 01-011 101.01	27.38/yd^3 68.00/yd^3 17.35/yd^3	25.00	10.00	70.00	yd^3
Crack Pouring	Pouring cracks in flexible pavement with asphalt material (may include cleaning with compressed air and covering with sand.	ARI CAL CAL NEV ND	103 01-041 01-042 101.07 414	3.38/gal 4.83/gal 6.41/gal 6.41/gal 1.18/gal	3.25	1.10	6.50	gal
Asphalt Concrete Overlay	Application of an asphalt concrete overlay usually less than about 2 inches.	TEX US		21.00*/ton 15.12*/ton	31.00	23.00	43.00	yd^3

*Cost per ton

Metric Conversions: 1 yd^2 = 0.83 m 1 yd^3 = 0.76 m 1 ton = 907 kg

Table 7. Unit Cost for Rigid Pavement Maintenance Operations (1977).

Descriptive Title	Maintenance Activity General Description	State	No.	Reported Avg. Unit Costs, Dollars	Suggested Unit Cost, Dollars			
					Avg.	Low	High	Unit of Measure
Mudjacking	Drilling holes and pumping concrete slurry under slab to fill the voids and raise the slab to grade.	CAL	02-011	7.28/yd^2	7.25			sq yd
Temporary Patching	Patch with bituminous materials.	CAL	02-021	25.50/yd^3	80	20	160	cu yd
Permanent Patching	Patch with P.C.C.	NEV	111.02	106.26/yd^3	375			cu yd
Joint Sealing	Cleaning joint, pour joint and apply sand as required.	CAL CAL NEV	02-042 02-043 111.05	5.57/gal 4.77/gal 10.00/gal	7.00	5.00	12.00	gal
Expansion Joint Repair	Cut along distressed area. Clean out area, place filler material.	NEV	111.06	6.79/lin ft	6.75	5.00	40.00	lin ft

Metric Conversion:

1 yd^2 = 0.83 m^2

1 yd^3 = 0.76 m^3

1 gal = 0.26 litre

1 ft = 0.305 m

Table 8. Representative Costs for Maintenance and Rehabilitation Activities - 1977.

Maintenance Activity	Cost Dollars* Per		Percent of Total Pavement Area Treated
	Sq. Yd.	Lane Miles	
Fog Seal - Partial Width	0.045	320	50 percent
Fog Seal - Full Width	0.06	420	100 percent
Chip Seal - Partial Width	0.06	420	15 percent
Chip Seal - Full Width	0.21	1,500	100 percent
Surface Patch - Hand Method	0.10	700	2.5 percent 1 inch thick
Surface Patch - Machine Method	0.08	560	10 percent 1 inch thick
Digout & Repair Hand Method	0.25	1,760	2 percent 4 inches thick
Digout & Repair - Machine Method	0.20	1,400	5 percent 6 inches thick
Crack Pouring	0.12	850	250 lin. ft. per station
Asphalt Concrete Overlay	1.90	13,400	100 percent 2 inches thick

*Costs are for square yards of total pavement surface maintained. For example, surface patching by the hand method may have been applied over only 5 percent of total pavement suface area, yet costs reported are for the total pavement area maintained or one mile of pavement.

Metric Conversions:

1 yd^2 = 0.83 m^2

1 mi = 1609 m

1 in. = 0.024 m

1 ft. = 0.305 m

Table 9. Maintenance Activities Associated with Flexible Pavement Distresses.

Type of Distress	Maintenance Activity	
Rutting	Surface Patch - Hand Surface Patch - Machine	Asphalt Concrete Overlay
Raveling	Fog Seal - Partial Width Fog Seal - Full Width	Chip Seal - Partial Width Chip Seal - Full Width
Flushing (Bleeding)	Overlay Chip Seal - Full Width	
Corrugations	Surface Patch - Hand Surface Patch - Machine	Digout & Repair - Hand Digout & Repair - Machine
Alligator Cracking	All maintenance operations could be used	
Longitudinal Cracking	Fog Seal - Partial Width Fog Seal - Full Width Crack Pouring	Chip Seal - Partial Chip Seal - Full Width Asphalt Cone - Overlay
Transverse Cracking	Crack Pouring Chip Seal - Full Width	Asphalt Concrete Overlay
Patching	Surface Patch - Hand Surface Patch - Machine Chip Seal - Full Width	Digout & Repair - Hand Digout & Repair - Machine Asphalt Concrete Overlay
Failures	Surface Patch - Hand Surface Patch - Machine Asphalt Cone Overlay	Digout & Repair - Hand Digout & Repair - Machine

Table 10. Pavement Rehabilitation Alternatives Defined.

Plan 1:	Two-inch asphalt concrete overlay with maintenance on a 7-year cycle (asphalt concrete $25.00 per ton).
Plan 2:	Chip seal plus 2 -inch asphalt concrete overlay with maintenance (chip seal $0.55 per square yard, asphalt concrete $25.00 per ton).
Plan 3:	Fabric reinforcement plus 2-inch asphalt concrete overlay with maintenance (fabric reinforcement $1.25 per square yard, asphalt concrete $25.00 per ton).
Plan 4:	Recycle existing 4 inches of material and blend a selected aggregate into recycled mixture. A 2-inch overlay is scheduled after 5 years (recycling at $20.00 per ton and overlay at $25.00 per ton).
Plan 5:	Recycling existing 4 inches of asphalt materials and 2 inches of asphalt concrete overlay with maintenance (recycling $16.00 per ton, asphalt concrete $25.00 per ton).
Plan 6:	Recycling existing 4 inches of asphalt materials and 2 inches of asphalt concrete overlay with maintenance which includes a 2-inch overlay (recycling $16.00 per ton, asphalt concrete $25.00 per ton).
Plan 7:	Recycling existing 4 inches of asphalt materials and 2 inches of asphalt concrete overlay with maintenance (recycling $20.00 per ton, asphalt concrete $25.00 per ton).
Plan 8:	Delay recycling 4 years and then recycle and add 2 inches of asphalt concrete overlay with maintenance (recycling $16.00 per ton, asphalt concrete $25.00 per ton).
Plan 9:	Heater-scarify to a depth of 1 to 1.5 inch and 2 inches of asphalt concrete overlay with maintenance (heater-scarification $0.90 per square yard, asphalt concrete $25.00 per ton).
Plan 10:	Aspahlt-rubber interlayer and 2 inches of asphalt concrete overlay with maintenance (asphalt-rubber interlayer $1.25 per square yard, aspahlt concrete $25.00 per ton).

Table 11. Cost Data Used to Analyze Rehabilitation Strategies.

Material or Operation	Cost	
	$/Ton	$/Sq. Yd.
Asphalt Concrete	25.00	1.25*
Recycle Asphalt Concrete	20.00	1.00*
Recycle Asphalt Concrete	16.00	0.80*
Chip Seal Coat		0.55
Fabric Interlayer		1.25
Heater-Scarification		0.90
Crack Sealing		0.15
Asphalt-Rubber Interlayer		1.25

*Cost per square yard for one-inch thickness.

Table 12. Rehabilitation Alternatives Cost Schedule.*

Year	Plan 1 2" A.C. Overlay	Plan 2 Seal Coat +2" A.C. Overlay	Plan 3 Fabric Reinforcement +2" A.C. Overlay	Plan 4 Recycle	Plan 5 Recycle +2" A.C. Overlay	Plan 6 Recycle +2" A.C. Overlay	Plan 7 Recycle +2" A.C. Overlay	Plan 8 Recycle +2" A.C. Overlay	Plan 9 Heater-Scarify +2" A.C. Overlay	Plan 10 Asphalt-Rubber Interlayer +2" A.C. Overlay
1980	2.50	3.05	3.75	4.00	5.70	5.70	6.50	0.15	3.40	3.75
1981								0.15		
1982								0.15		
1983	0.08							0.15		
1984	0.13	0.08	0.08					6.50	0.08	0.08
1985	0.15	0.13		2.50						
1986	0.15	0.15	0.13						0.13	0.13
1987	2.50	0.15								
1988		0.15	0.15		0.08	0.08	0.08		0.15	0.15
1989		2.50								
1990	0.08		2.50		0.13	0.13	0.13		2.50	2.50
1991	0.13			0.08				0.08		
1992	0.15	0.08		0.15	0.15	0.15				
1993	0.15	0.13	0.08	0.13				0.13	0.08	0.08
1994	2.50	0.15	0.13		0.15	2.50	0.15		0.13	0.13
1995		0.15	0.15	0.15				0.15	0.15	0.15
1996		3.05	0.15		0.15		0.15		0.15	0.15
1997	0.08		0.15	0.15				0.15	0.15	0.15
1998	0.13		0.15		0.15	0.08	0.15		0.15	0.15
1999	0.15		0.15	0.15				0.15	0.15	0.15
2000	0.15	0.08	0.15		0.15	0.13	0.15		0.15	0.15

*Numbers represent costs per square yard.

Table 13. Life-Cycle Calculations for Plan 1.

Year		Cost, Dollars Per Square Yard	Present Worth Factor, 8%	Present Worth, Dollars
Initial Cost		2.50	1.0000	2.500
1			0.9259	
2			0.8573	
3	RM*	0.08	0.7938	0.064
4	RM	0.13	0.7350	0.096
5	RM	0.15	0.6806	0.102
6	RM	0.15	0.6302	0.095
7	Overlay	2.50	0.5835	1.459
8			0.5403	
9			0.5002	
10	RM	0.08	0.4632	0.037
11	RM	0.13	0.4289	0.056
12	RM	0.15	0.3971	0.060
13	RM	0.15	0.3677	0.055
14	Overlay	2.50	0.3405	0.851
15			0.3152	
16			0.2919	
17	RM	0.08	0.2703	0.022
18	RM	0.13	0.2502	0.033
19	RM	0.15	0.2317	0.035
20	RM	0.15	0.2145	0.032
Salvage Value		0.00	0.2145	-0.000

TOTAL = 5.497 ←

Uniform Annual Cost = Present Worth x Capital Recovery Factor.
= 5.497 x 0.10185
= 0.560 ←

*RM = Routine maintenance

Overlay - Asphalt concrete overlay

Table 14. Life-Cycle Calculations for Plan 7.

Year		Cost, Dollars Per Square Yard	Present Worth Factor, 8%	Present Worth, Dollars
Initial Cost		6.50	1.0000	6.500
1			0.9259	
2			0.8573	
3			0.7938	
4			0.7350	
5			0.6806	
6			0.6302	
7			0.5835	
8	RM*	0.08	0.5403	0.043
9			0.5002	
10	RM	0.13	0.4632	0.060
11			0.4289	
12	RM	0.15	0.3971	0.060
13			0.3677	
14	RM	0.15	0.3405	0.051
15			0.3152	
16	RM	0.15	0.2919	0.044
17			0.2703	
18	RM	0.15	0.2502	0.038
19			0.2317	
20	RM	0.15	0.2145	0.032
Salvage Value		0.00	0.2145	-0.000

TOTAL = _____ Total = 6.829 ←

Uniform Annual Cost = Present Worth x Capital Recovery Factor.

= 6.828 x 0.1085

= 0.695 ←

*RM = Routine maintenance

Table 15. Calculation Form for Life-Cycling Costing.

Year	Cost, Dollars Per Square Yard	Present Worth Factor, 8%	Present Worth, Dollars
Initial Cost		1.0000	
1		0.9259	
2		0.8573	
3		0.7938	
4		0.7350	
5		0.6806	
6		0.6302	
7		0.5835	
8		0.5403	
9		0.5002	
10		0.4632	
11		0.4289	
12		0.3971	
13		0.3677	
14		0.3405	
15		0.3152	
16		0.2919	
17		0.2703	
18		0.2502	
19		0.2317	
20		0.2145	
Salvage Value		0.2145	

TOTAL = _____ Total = _____ ←

Uniform Annual Cost = Present Worth x Capital Recovery Factor.

= _____ x 0.10185

= _____ ←

Table 16. Cost and Energy Summary.

Plan No.	Method	Energy, BTU/Sq. Yd.		Cost, Dollars/Sq. Yd.		
					20 Year Life	
		Initial	20 Year Life	Initial	0 Percent	8 Percent
1	2" AC Overlay	57,800	200,000	2.50	9.03	5.50
2	Seal Coat + 2" AC Overlay	61,700	203,000	3.05	9.85	5.80
3	Fabric + 2" AC Overlay	60,000	145,000	3.75	7.72	5.44
4	Recycle	119,600	190,000	4.00	7.16	5.91
5	Recycle + 2" AC Overlay	177,400	195,000	5.70	6.66	6.03
6	Recycle + 2" AC Overlay	177,400	244,000	5.70	8.77	6.76
7	Recycle + 2" AC Overlay	177,400	195,000	6.50	7.46	6.83
8	Recycle + 2" AC Overlay	2,200	201,000	0.15	7.76	5.52
9	Heater-Scarify + 2" AC Overlay	74,800	160,000	3.40	7.37	5.09
10	Asphalt Rubber Interlayer + 2" AC Overlay	64,000	149,000	3.57	7.72	5.44

*Equal annual costs assuming 0 and 8 percent rate of return.

Table 17. Construction Cost Index History 1960-1980.

	Monthly												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
1960	812	813	813	815	823	827	829	830	831	830	830	831	824
1961	834	834	834	838	847	850	854	854	854	854	855	855	847
1962	855	858	861	863	872	873	877	881	881	880	880	880	872
1963	883	883	884	885	894	899	909	914	914	916	914	915	901
1964	918	920	922	926	930	935	945	948	947	948	948	948	936
1965	948	957	958	957	958	969	977	934	986	986	986	988	971
1966	983	997	998	1006	1014	1029	1031	1033	1034	1032	1033	1034	1019
1967	1039	1041	1043	1044	1059	1068	1078	1089	1092	1096	1097	1098	1070
1968	1107	1114	1117	1124	1142	1154	1158	1171	1186	1190	1191	1201	1155
1969	1216	1229	1238	1249	1258	1270	1283	1292	1285	1299	1305	1305	1269
1970	1309	1311	1314	1329	1351	1375	1414	1418	1421	1434	1445	1445	1385
1971	1469	1467	1496	1513	1551	1589	1618	1629	1654	1657	1665	1672	1581
1972	1686	1691	1697	1707	1735	1761	1772	1777	1786	1794	1808	1816	1753
1973	1838	1850	1859	1874	1880	1896	1901	1902	1929	1933	1935	1939	1895
1974	1940	1940	1940	1961	1961	1993	2040	2076	2089	2100	2094	2101	2020
1975	2103	2128	2128	2135	2164	2205	2248	2274	2275	2293	2292	2297	2212
1976	2305	2314	2322	2327	2357	2410	2414	2445	2465	2478	2486	2490	2401
1977	2494	2505	2513	2514	2515	2541	2579	2611	2644	2675	2659	2669	2577
1978	2672	2681	2693	2698	2783	2853	2821	2829	2851	2851	2861	2869	2776
1979	2872	2877	2886	2886	2889	2984	3052	3071	3120	3122	3131	3140	3003
1980	3132	3134	3159	3151	3139	3198							

From Reference 3.

How ENR builds the Index: 200 hours of common labor at the 20-cities average rate, plus 25 cwt of standard structural steel shapes at the mill price, plus 22.56 cut (1.128 tons) of Portland cement at the 20-cities average price, plus 1,088 board feet of 2 x 4 lumber at the 20-cities average price.

Table 18. Bid Price Trends on Federal-Aid Highway Contracts.

			Surfacing			Structures					
	Excavation Price (y^3)	Index	PCC Price (y^2)	Bit. Conc. Price (t)	Combined Index	Rein. Steel Price (lb)	Struc. Steel Price (lb)	Struc. Conc. Price (y^3)	Combined Index	Highway Bid Price Index	ENR Building Cost Index
1967	0.54	100.0	4.43	6.47	100.0	0.131	0.247	70.30	100.0	100.0	100.0
1970	0.66	121.8	5.42	8.04	123.3	0.163	0.338	92.73	132.2	125.6	124.4
1971	0.67	123.8	6.06	8.54	134.5	0.177	0.348	92.02	138.5	131.7	141.1
1972	0.72	133.4	6.25	9.22	141.9	0.181	0.342	100.17	140.6	138.2	156.0
1973 Av.	.80	147.1	6.87	9.99	154.8	0.207	0.373	111.83	156.5	152.4	169.3
Q1	0.67	124.7	6.57	9.85	150.3	0.181	0.295	109.34	141.9	137.8	
Q2	.75	138.0	6.36	9.90	148.2	0.193	0.352	113.51	153.4	145.9	
Q3	.81	149.5	7.10	9.61	154.7	0.212	0.422	110.60	162.1	155.1	
Q4	.93	172.7	7.43	10.83	167.7	0.233	0.379	113.51	162.0	167.8	
1974 Av.	1.00	184.1	8.67	14.74	211.3	0.340	0.551	136.80	214.5	201.8	119.2
Q1	.97	179.1	8.17	13.28	194.6	0.281	0.459	129.64	190.2	187.4	
Q2	.96	178.0	8.48	15.77	216.8	0.342	0.555	137.07	215.4	201.4	
Q3	1.02	187.9	8.82	14.64	212.4	0.371	0.577	152.57	233.7	209.7	
Q4	1.03	190.6	9.10	15.18	219.7	0.362	0.648	130.33	224.1	209.9	
1975 Av.	1.03	190.6	8.62	15.13	213.8	0.297	0.554	138.76	210.5	203.8	194.3
Q1	1.02	188.1	9.84	13.95	219.1	0.332	0.577	140.93	219.7	207.3	
Q2	1.00	184.9	8.22	14.35	203.2	0.320	0.542	139.85	213.1	199.3	
Q3	1.02	188.8	8.49	15.58	215.5	0.283	0.556	142.13	211.5	203.9	
Q4	1.10	202.6	9.00	16.41	227.7	0.277	0.548	131.90	207.9	209.8	
1976 Av.	1.03	191.2	8.65	15.07	213.7	0.257	0.493	138.75	198.1	200.4	212.1
Q1	1.04	192.0	7.70	16.28	212.3	0.251	0.543	133.72	199.3	200.3	
Q2	1.05	194.3	8.56	14.13	205.5	0.242	0.510	145.65	203.1	200.4	
Q3	1.03	191.1	9.18	15.12	219.4	0.264	0.438	135.28	189.6	199.0	
Q4	1.01	187.3	9.17	14.76	217.4	0.271	0.481	141.34	200.4	200.4	

Table 18. (continued).

	Excavation Price (y^3)	Index	Surface: PCC Price (y^2)	Surface: Bit. Conc. Price (t)	Surface: Combined Index	Structures: Rein. Steel Price (lb)	Structures: Struc. Steel Price (lb)	Structures: Struc. Conc. Price (y^3)	Structures: Combined Index	Highway Bid Price Index	ENR Building Cost Index
1977 Av.	1.16	215.2	9.68	15.47	228.4	0.272	0.520	143.51	206.8	216.4	229.9
Q1	1.03	189.8	8.69	14.88	212.6	0.262	0.562	139.60	207.6	202.2	
Q2	1.16	214.6	9.41	15.29	224.1	0.268	0.499	149.54	208.3	215.4	
Q3	1.19	219.5	10.05	15.32	231.8	0.273	0.462	139.42	196.9	215.9	
Q4	1.29	237.7	10.32	16.94	247.1	0.285	0.536	148.34	214.1	233.0	
1978 Av.	1.54	233.7	11.49	17.15	262.3	0.315	0.603	172.41	244.4	264.9	249.1
Q1	1.13	209.1	9.68	16.10	233.3	0.283	0.563	151.43	219.4	219.5	
Q2	1.43	263.8	11.96	17.54	270.6	0.310	0.570	171.78	239.5	258.1	
Q3	1.84	339.8	12.04	17.11	268.4	0.346	0.638	198.97	268.9	296.1	
Q4	1.90	350.3	13.06	18.09	237.5	0.334	0.681	176.17	259.0	302.7	
1979 Av.(p)	1.62	298.7	13.47	21.21	315.7	0.421	0.759	220.28	313.1	308.3	270.7
Q1	1.48	278.2	11.59	18.35	272.3	0.381	0.737	195.60	286.6	277.2	
Q2	1.54	284.7	12.91	20.72	305.4	0.411	0.749	202.82	297.5	294.9	
Q3	1.31	334.9	15.09	22.08	341.1	0.429	0.755	215.41	310.1	328.8	
Q4 (p)	1.86	343.6	16.85	23.67	373.6	0.489	0.804	240.14	342.6	352.1	

After References 3 and 4.

Table 19. Equipment Price Indexes.

	Jan. 1980	% Chg. 10/79-1/80	% Chg. 1/79-1/80
All construction equipment	275.4	+4.8	+12.2
Power cranes, excavators & equip.	266.8	+3.7	+10.8
Crane, hydr., rbbr-tired, 12-18 tons (a)	230.2	+1.3	+11.4
trk-mntd, 15-25 tons (e)	174.0	+6.4	+7.8
25-50 tons (e)	191.1	--	+13.5
cable, trk-mntd, 50-100 tons (e)	196.9	+2.9	+7.9
crawler, 50-100 tons (e)	226.9	+4.9	+10.5
Excavators, hydr. (e)	199.7	+3.7	+12.5
Bucket, clamshell, 1/4 cu yd	357.3	--	+13.5
dragline, 1/4 cu yd	341.2	+4.2	+13.3
Backhoes	244.4	+5.6	+13.7
Scraper, 18 & under 30 cu yd	273.5	+4.5	+13.9
30 & under 37 cu yd	--	--	--
Grader, 115-144 bhp	288.5	+5.9	+12.7
Tractors	282.2	+5.2	+12.6
Wheel, off-highway, 300-399 twhp	301.3	+3.7	+13.4
400 twhp & over	--	--	--
Crawler, 20-59 net ang hp	231.0	+4.8	+10.8
90-153 net ang hp	295.3	+3.0	+11.2
180-259 net ang hp	316.2	+1.2	+11.5
260 & over net ang hp	308.1	+1.4	+10.8
Shovel-loader, crawler, 90-129 hp	266.9	+2.8	-14.5
Rbbr-tired, 2 1/2 & under 3 1/2 cu yd (e)	202.1	+3.0	+11.0
Rbbr-tired, 5 & under 7 1/2 cy yd (e)	229.5	+2.3	+14.4
Off-highway trucks, and dump, 50-ton	299.6	+4.4	+14.4
Roller, tandem	--	--	--
pneumatic	--	--	--
vibratory (d)	--	--	--
Dewatering pump, 10 m gph	253.4	0	+13.7
90 m gph	287.4	0	+7.2
Portable air compressors	152.6	+4.8	+14.7
Mixers, pavers, spreaders	223.2	+2.1	+9.4
Concrete mix plant, mobile (c)	198.5	+1.6	+9.5
Truck mixer, 7 cu yd	208.7	+4.2	+16.1
Slipform paver (d)	151.7	-14.1	-10.2
Bituminous batch plant, portable (b)	235.5	+3.7	+9.1
Bituminous spreader	249.1	+1.6	+5.9
Crushing plant, portable (b)	259.1	+8.7	+16.1
Welding machines and equipment	232.7	+2.2	+7.6

Source Bureau of Labor Statistics, 1967 = 100

(a) Dec. '67 = 100, (b) Dec. '68 = 100, (c) Dec. '69 = 100, (d) Dec. '70 = 100, (e) Dec. '72 = 100.

After Reference 3.

Table 20. Cost Trends.

Highway Maintenance and Operation[1]

1967 = Base Year

Year	Labor	Material	Equipment	Overhead	Total
1950	43.58	74.53	57.66	57.07	51.31
1951	47.76	81.07	64.34	62.23	56.41
1952	51.15	81.99	66.86	65.05	59.28
1953	52.00	82.54	68.76	65.73	60.33
1954	54.89	83.49	70.40	66.42	62.55
1955	55.94	82.80	74.24	67.71	64.09
1956	58.70	86.91	74.06	70.55	66.31
1957	63.20	90.86	75.66	78.22	70.28
1958	65.74	92.27	78.91	81.21	72.90
1959	67.82	92.40	83.15	81.88	75.17
1960	71.02	94.68	86.98	84.19	78.35
1961	73.25	95.18	87.19	85.08	79.82
1962	76.06	96.66	88.76	86.47	82.09
1963	79.46	96.87	89.25	88.05	84.32
1964	81.79	97.48	91.25	89.98	86.35
1965	85.69	99.23	94.23	92.01	89.66
1966	98.02	99.68	96.70	96.23	97.76
1967	100.00	100.00	100.00	100.00	100.00
1968	103.63	102.03	100.42	105.03	102.79
1969	113.71	106.24	104.24	110.24	110.44

[1]These data are prepared for the unit cost information submitted each year by State highway departments, and cover both physical maintenance and major traffic service items including snow and ice control. Previous issues of this table used base period 1957-59.

After Reference 5

Table 20. (Continued.)

Year	Labor	Material	Equipment	Overhead	Total
1970	122.02	111.03	106.56	116.81	116.78
1971	129.67	117.37	107.93	122.76	122.68
1972	138.21	124.27	119.98	128.71	131.68
1973	148.04	130.42	133.70	134.66	141.75
1974	160.67	170.41	153.50	140.61	158.65
1975	173.15	198.74	170.58	145.56	172.97
1976	192.99	192.74	184.37	152.51	188.08
1977	211.89	202.66	194.17	158.51	202.92
1978	226.70	233.41	208.63	164.41	218.80

After Reference 5.

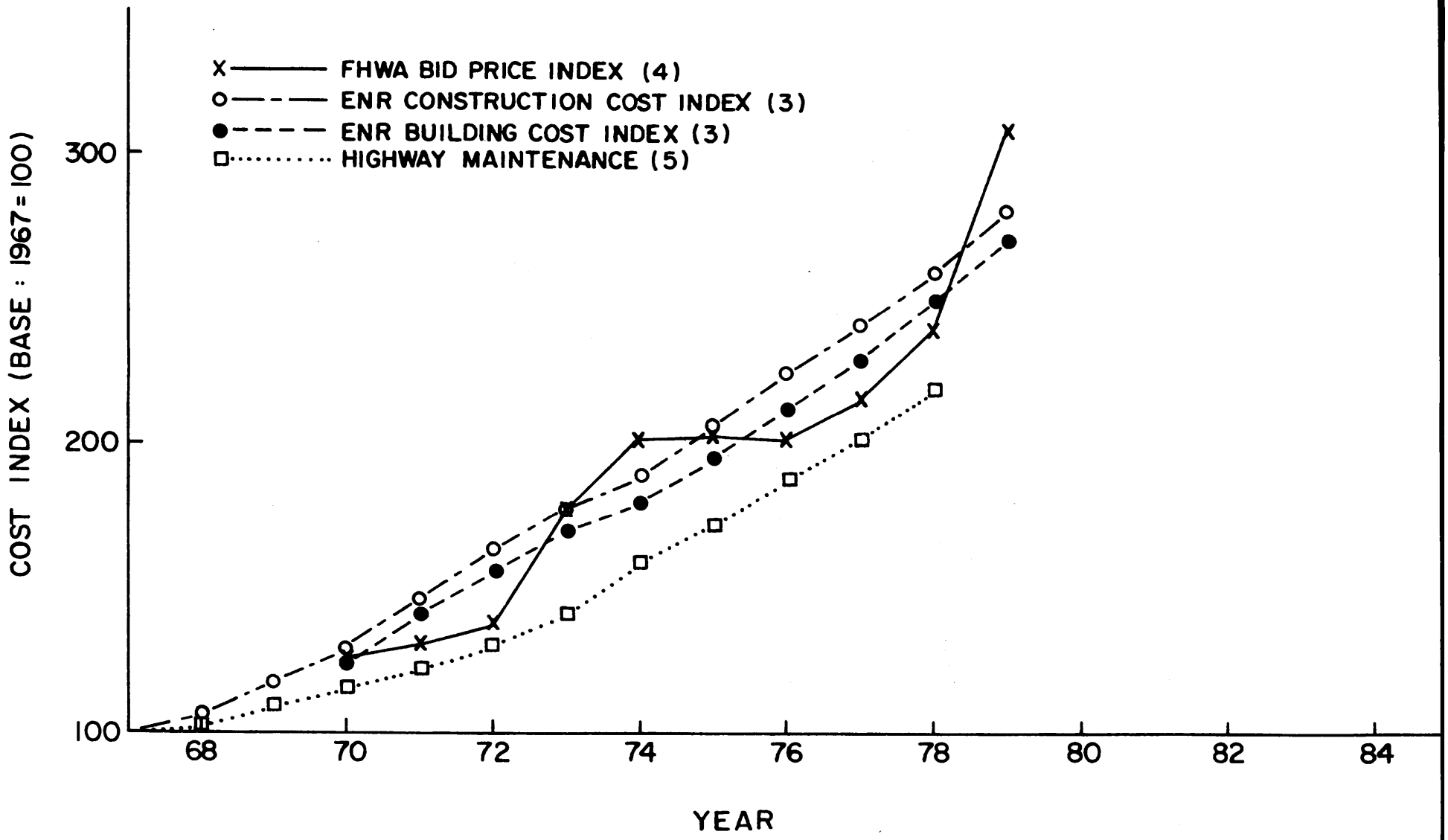

FHWA BID PRICE INDEX (4)
ENR CONSTRUCTION COST INDEX (3)
ENR BUILDING COST INDEX (3)
HIGHWAY MAINTENANCE (5)
COST INDEX (BASE : 1967 = 100)
100
200
300
68
70
72
74
76
78
80
82
84
YEAR

Figure 1.

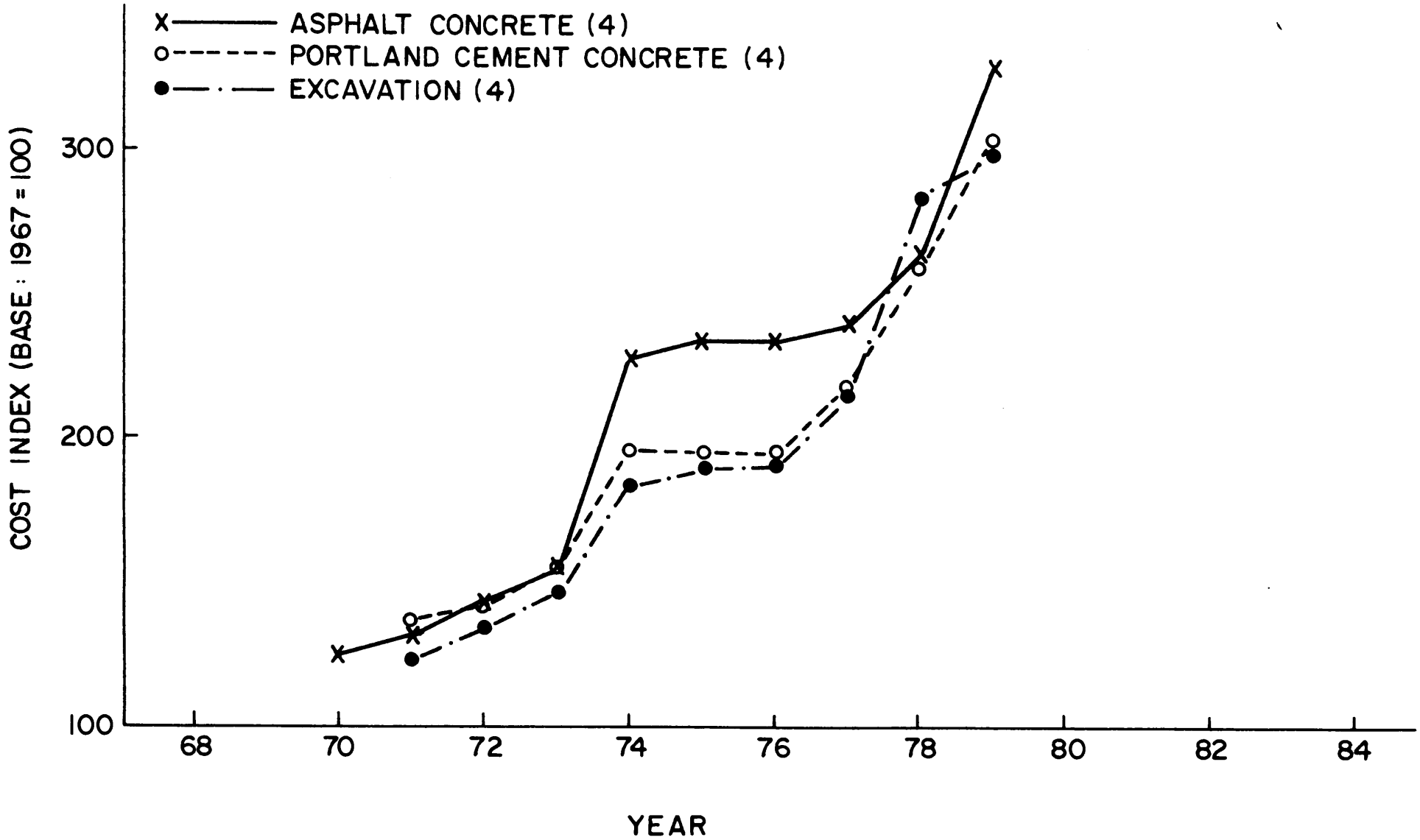


Figure 2. Pavement Construction Indexes.

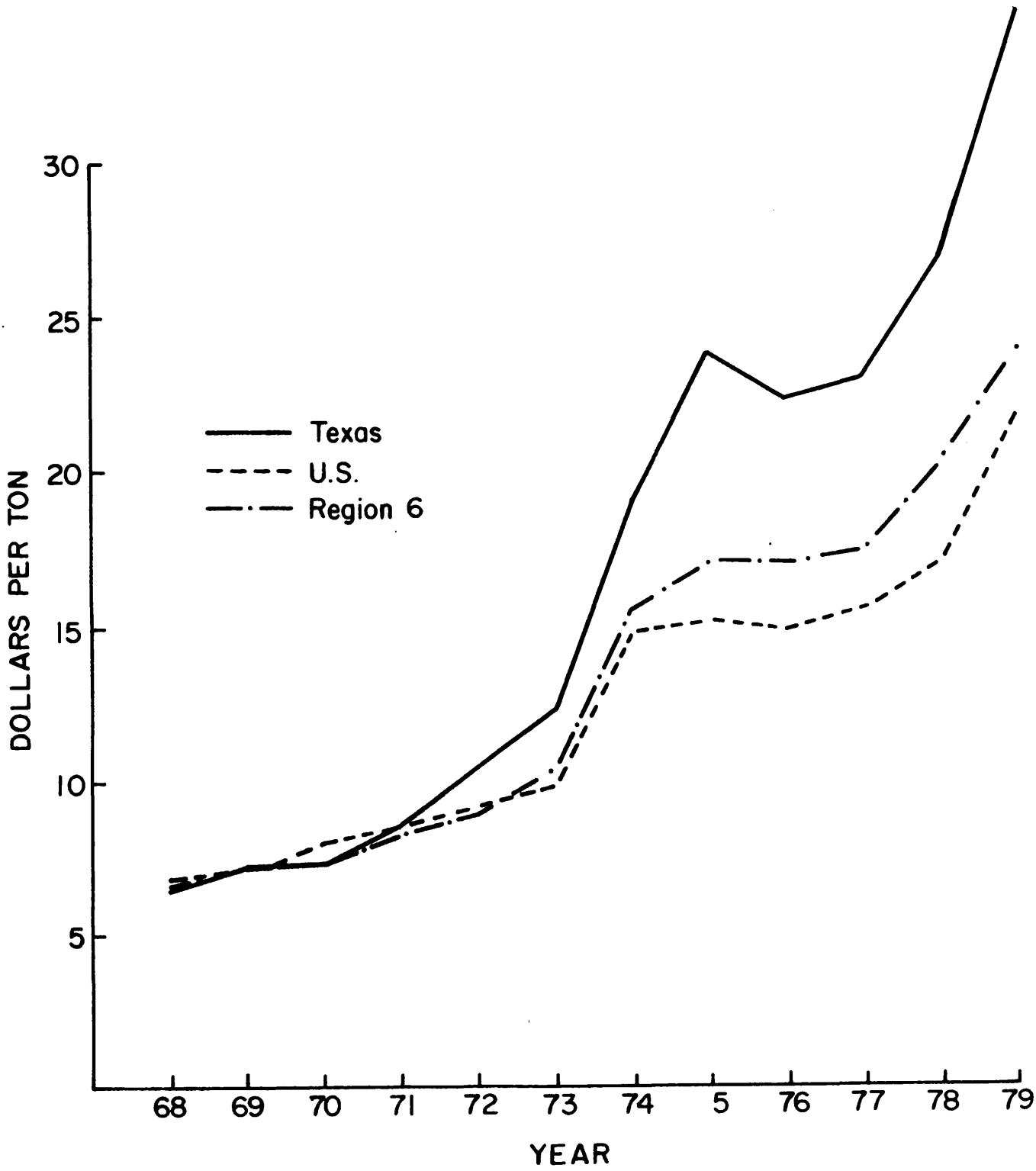


Figure 3. Average Annual Contract Price for Bituminous Concrete. After Reference 4.

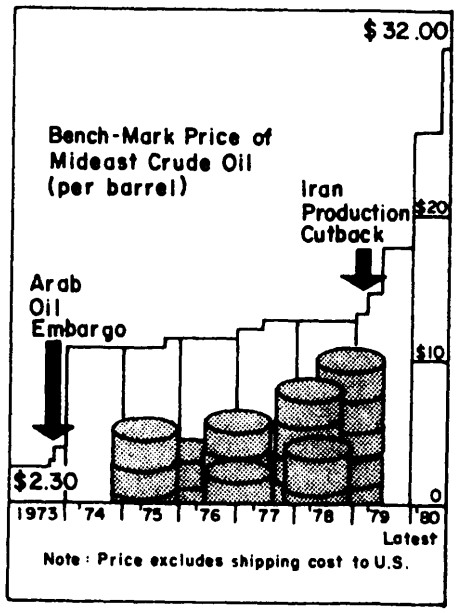


Figure 4. Imported Mideast Crude Oil Price Trends 1973 to 1980. After Reference 7.

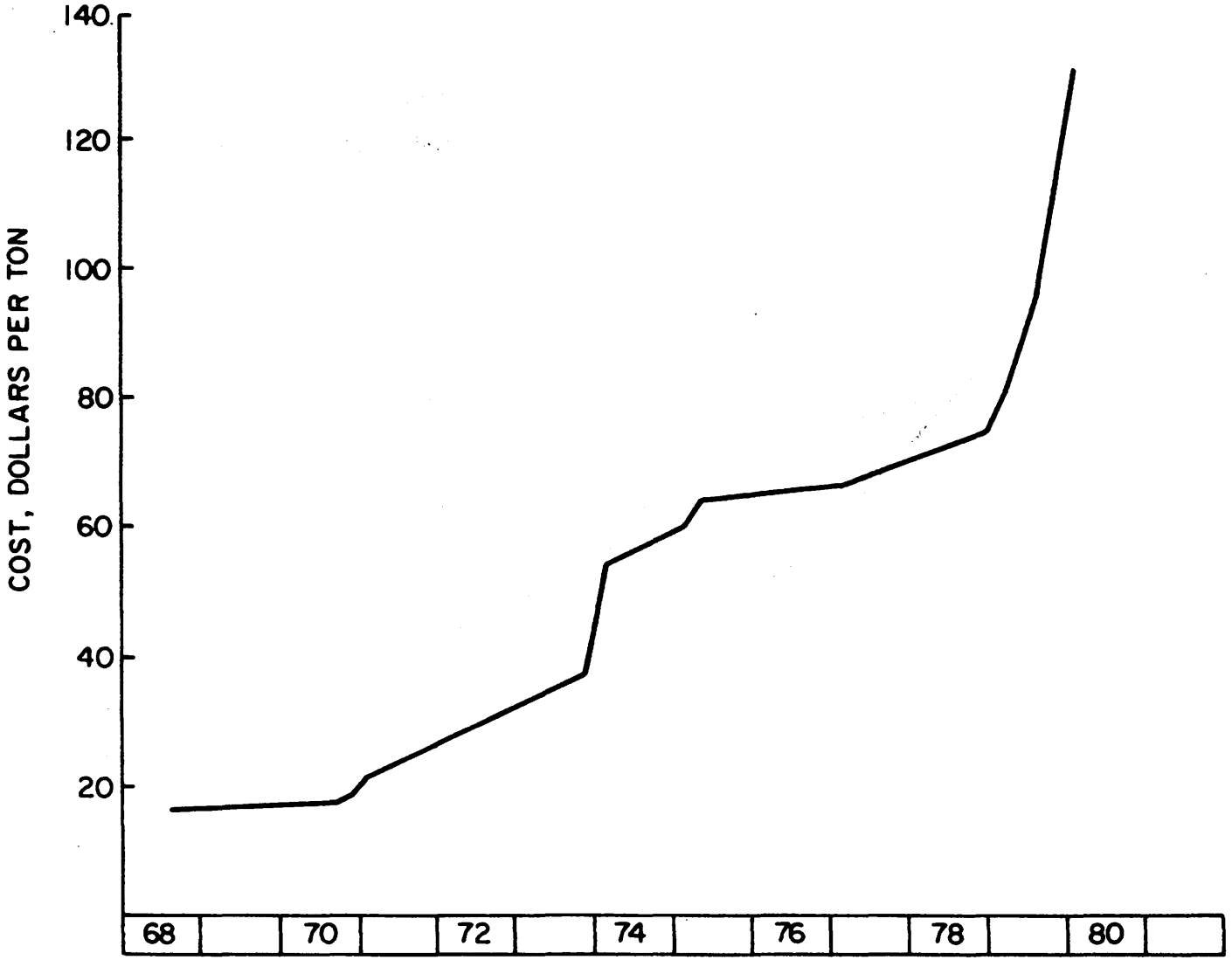


Figure 5. Posted Price of AC-10/20 Asphalt Cement - Texas.

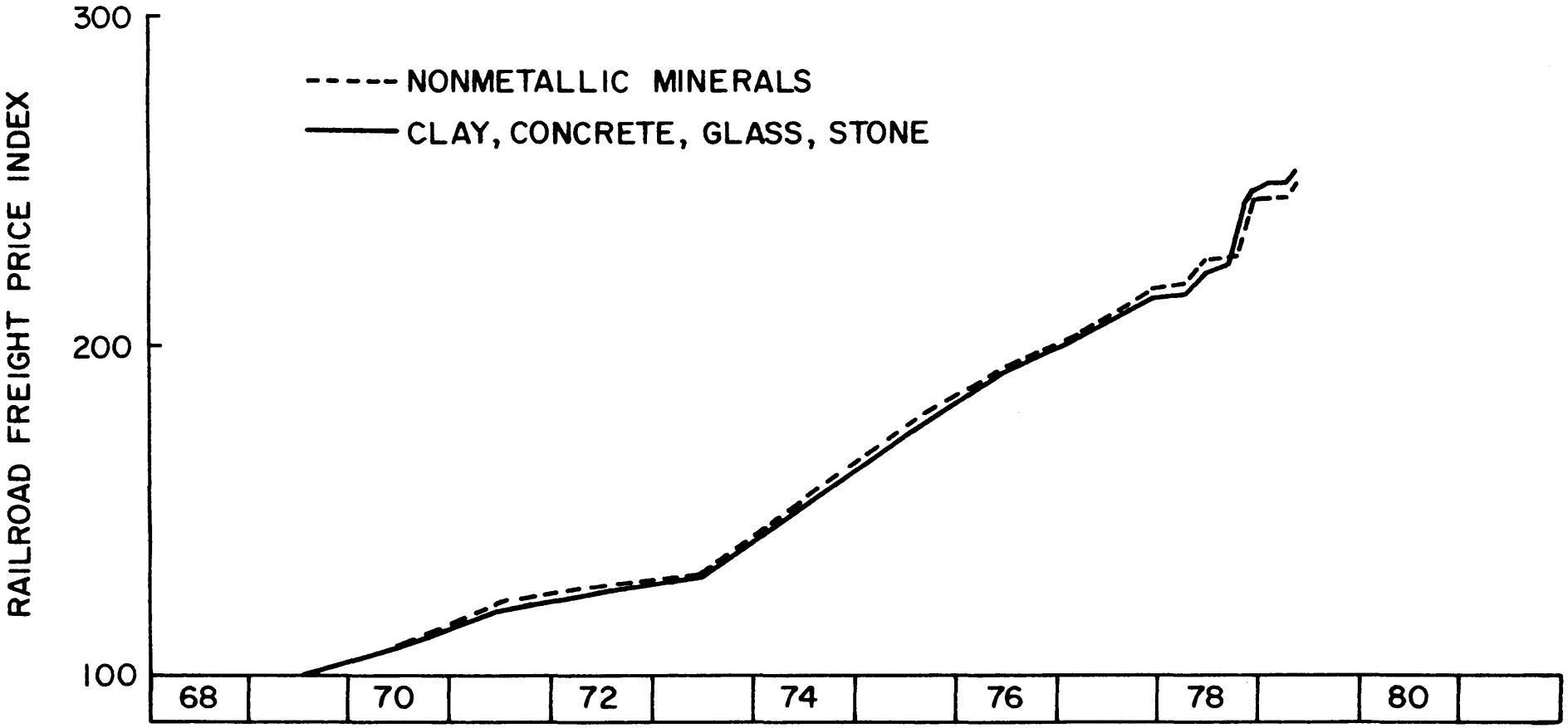


Figure 6. United States Price Index for Railroad Freight.

After References 8 and 9.

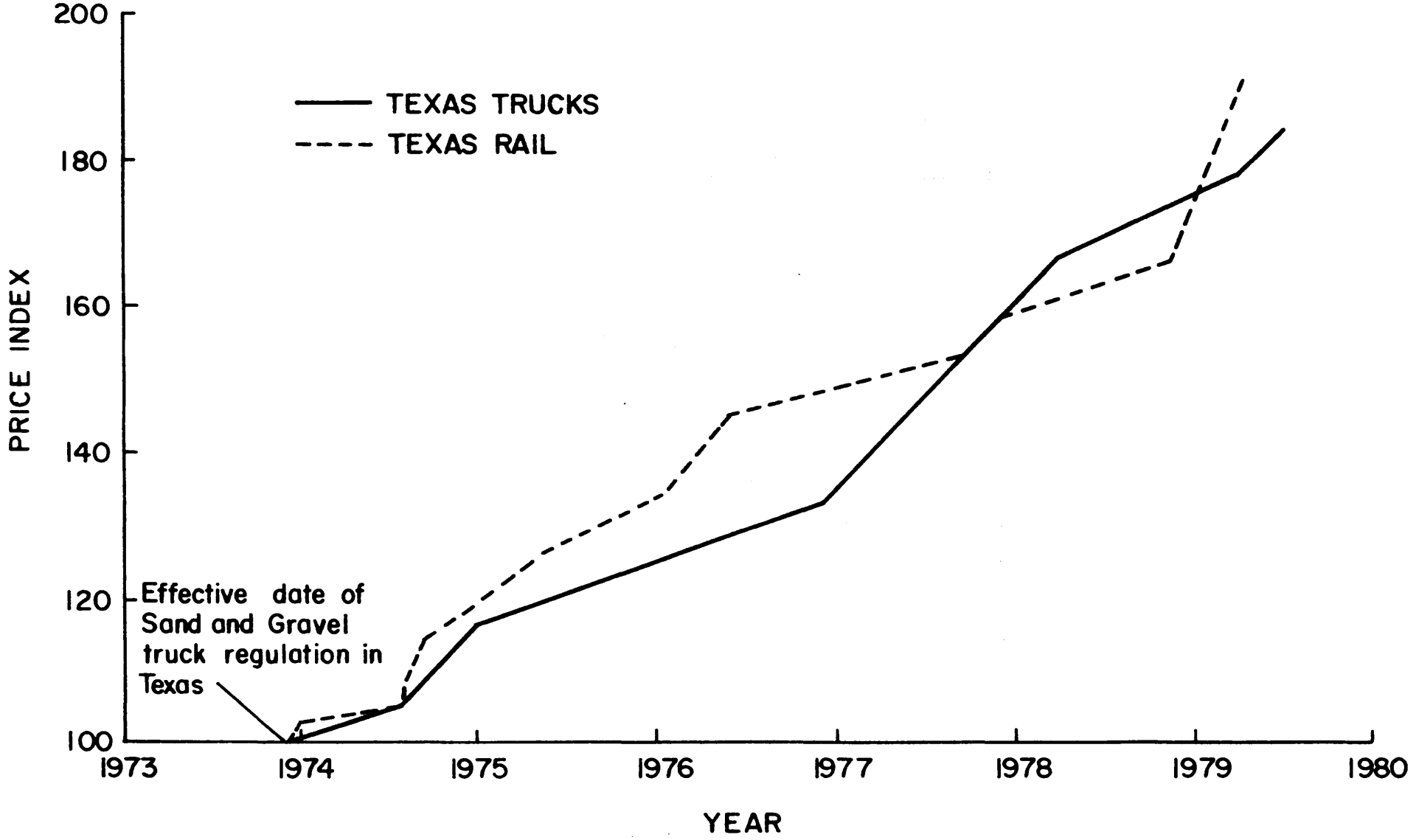
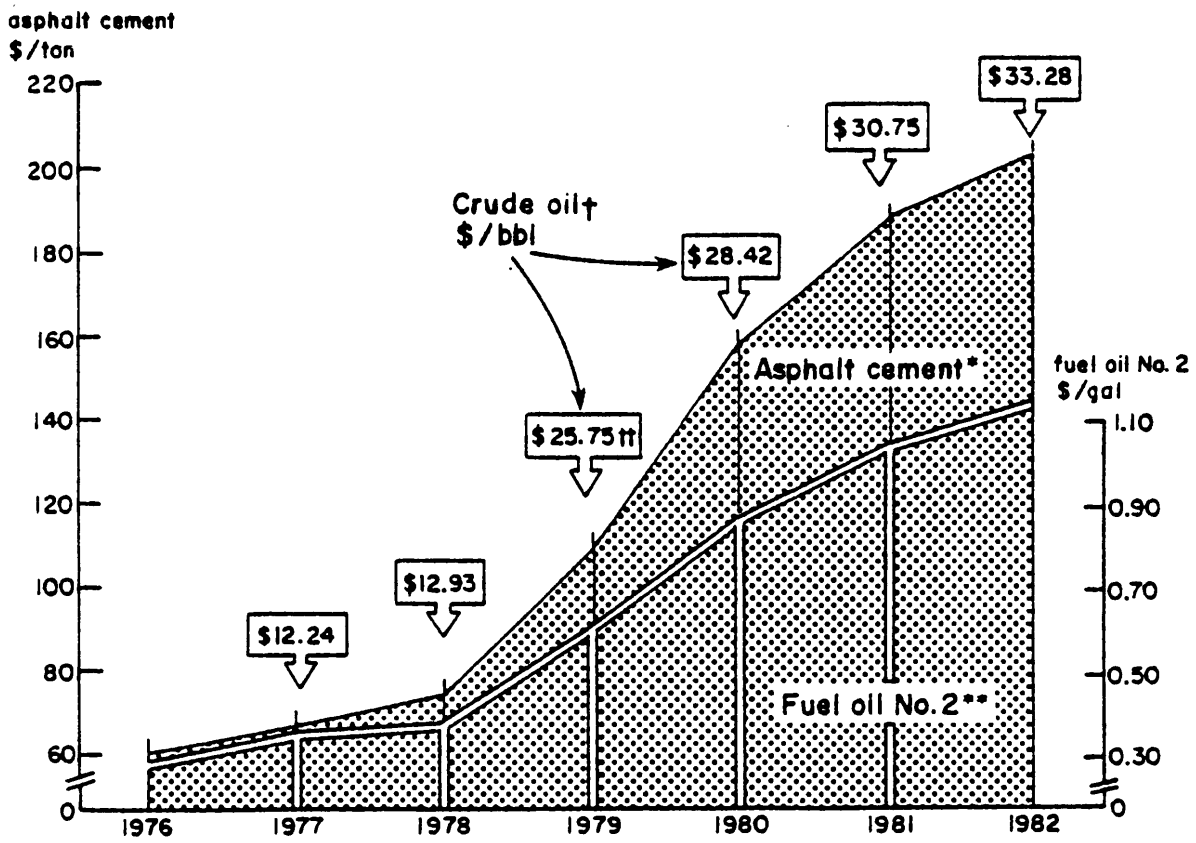


Figure 7. Texas Intrastate Truck and Rail Transportation Index.



*Source: National Asphalt Pavement Association, Engineering News-Record, Department of Energy. *ENR's 20-city average price **average refiner's selling price (DOE) †composite refiner aquisition cost (DOE). ††NAPA estimate*

Figure 8. Asphalt Cement Price Forecast: 1980-82.
After Reference 11.

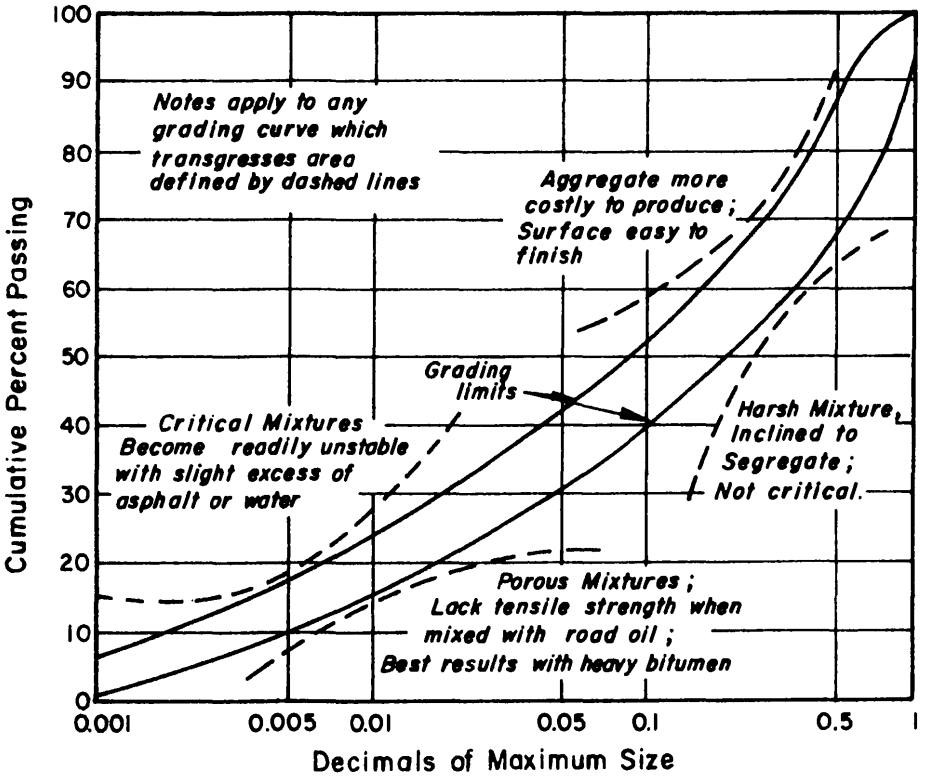


Figure 9. Grading chart illustrating grading specifications established to avoid undesirable conditions.

After Hveem.