CONDITION OF TEXAS PAVEMENTS

1986-1990 PAVEMENT EVALUATION SYSTEM
ANNUAL REPORT

TEXAS DEPARTMENT OF TRANSPORTATION
PAVEMENT MANAGEMENT

MARCH, 1992

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EXECUTIVE SUMMARY

This report summarizes the results of the 1990 Pavement Evaluation System (PES) Survey of the Texas highway network and describes statewide pavement condition and rehabilitation needs. Also historical trends over the last five years (1986-1990) are reported. Analysis of the data has identified the following:

1. *The condition of the Texas highway network decreased after five consecutive years of improvement. Almost 90 percent of the network is in good to very good condition.*

2. *Approximately $512 million is needed for pavement rehabilitation work on 6,291 lane miles. This is slightly less than the funding needed in 1989, when $540 million was needed to rehabilitate 7,076 lane miles.*

3. *Some changes due to Texas Reference Marker System conversion were noticeable, but overall, 95 percent of the PES sections converted successfully.*

4. *The expected variability in the PES distress ratings remains at ±15 points. In 1990, District and audit raters agreed within ±15 points on 79.5 percent of the PES audit sections, compared to 82.2 percent in 1989.*

5. *The pavement deflection data analysis indicated that 34.1 percent of the tested mileage could be considered "structurally poor". The data also indicated that 29.4 percent of these "poor" pavements were in very good condition. These "poor" pavements with very good condition may be the result of using seal coats or thin overlays in lieu of reconstruction or rehabilitation due to funding constraints. These "poor" sections typically experience greater and more rapid changes in condition (up or down), may require more maintenance, and may not last as long.*

6. *Rutting continues to be a significant problem. Approximately 30 percent of the sections surveyed had at least one percent rutting in excess of ½" .*

7. *Construction expenditures have declined slightly from last year, which when normalized to 1984 dollars, show an even sharper decline beginning in 1988. Maintenance expenditures decreased slightly since last year, dropping off sharply from 1988 expenditures when inflation is considered.*

8. *Probability programs forecast the future condition of Asphalt Concrete Pavement to drop noticeably with the greatest losses attributable to load-related distresses. Ride quality is expected to improve, but may become difficult to maintain as load-related distresses evolve into base and subgrade problems.*

CHAPTER 1
INTRODUCTION

The Texas Pavement Evaluation System (PES) is a tool available to the Department of Transportation (DOT) Administration and Districts to: determine past and present conditions, estimate rehabilitation needs, and compare different geographical areas of the Texas highway network. PES is a combination of field surveys, computer programs, and mainframe database files. The field surveys include: surface distress, ride quality, structural strength, and surface friction (optional). These surveys are performed each year on a statistically representative sample of the network. The surface distress and ride quality surveys are conducted between September and December when the pavement is in its most stable state and construction is at a minimum. The structural strength survey is an extensive data collection procedure and requires year round collection. Surface friction measurement are conducted on request anytime throughout the year. There are eight years of survey results (starting in 1983) stored on mainframe files. PES provides specific reports to aid Department personnel in collecting, storing, and evaluating the data. Following is an overview of PES survey procedures and score interpretations that will be used in this report.

Surface Distress Survey

In 1990 D-18's Pavement Management (PM) section trained between 150-200 District personnel how to collect surface distress data, which is a primary factor in several PES scores. These personnel attend a three-day course for beginners and one day refresher course for experienced raters. They then travel in teams of two, recording their ratings on separate forms for three major pavement types: Asphaltic Concrete Pavement (ACP), Continuous Reinforced Concrete (CRC), and Jointed Concrete Pavement (JCP). The distress types collected for ACP are rutting, patching, failures, block cracking, alligator cracking, longitudinal cracking, and transverse cracking. The distress types for CRC are spalled cracks, punchouts, asphalt patches, and concrete patches. The distress types for JCP are failed joints and cracks, failures, slabs with longitudinal cracks, shattered slabs, and concrete patches. For more information on the PES visual distress survey, contact D-18PM to obtain the "*PES Rater's Manual*".

In 1990, data were collected on 17,391 sections which is 33,314 mainlane miles, or 44.4 percent of the Texas highway network.

Ride Quality Survey

The Department maintains 17 response type road roughness meters (RTRRMs), known as SIometers, for the collection of ride quality data. This equipment is operated by trained District personnel. The SIometer unit consists of an accelerometer, a processing computer, and a data storage computer. Ride quality is reported in terms of a unit called the Serviceability Index (SI) which varies from 0 (for very rough pavements) to 5 (for very smooth pavements). Siometer calibrations are done in Austin each year to ensure consistency in survey results. To ensure consistent data during the data collection season, an equipment verification is performed regularly. Ride Quality data is a factor in two PES scores and cán be used alone in determining needs and trends.

In 1990, data were collected on 17,391 sections which is 33,314 mainlane miles, or 44.4 percent of the Texas highway network. This was the same amount of mileage collected in the surface distress survey.

Structural Strength Survey

The Department has 13 automated deflection measuring devices known as Falling Weight Deflectometers (FWD). The FWD is used to collect structural strength data. The FWD is a non-destructive testing device which measures structural integrity of highway pavements by impact loading the pavement surface and measuring the resulting deflections. The results are reported in parameter called the Structural Strength Index (SSI) which varies from 0 (for a weak pavement) to 100 (for a strong pavement). Deflection data for PES is only collected on flexible pavements, and only on about one-third of the statistical sample. SSI is an indicator of a pavement's structural integrity, a stand alone score and not used in any other PES scores.

In 1990, 6,516 sections or 12,866 mainlane miles were tested for structural strength. This is 19 percent of the Texas flexible pavement network, or 18 percent of the entire highway network.

Surface Friction Survey

The Department currently uses a locked-wheel skid trailer and tow vehicle to measure surface friction (skid). Currently there are five units in the field with plans to add two more units. The skid trailer is a two-wheeled trailer towed behind a truck at 40 miles per hour. The left trailer wheel is locked at periodic intervals on a wetted surface and the resulting friction force is measured. This friction force is known as a skid number (SN) and ranges from 0 (for a pavement with very low friction-*slick)* to 100 (for a pavement with very high friction). This survey is optional and not used in any PES scores. The skid survey can be used to evaluate effects of aggregate type, asphalt mix design, and pavement construction methods on skid resistance over time.

In 1990, skid resistance data were collected on 2,607 sections or 5,096 mainlane miles. This voluntary survey covered 7.4 percent of the Texas highway network.

Reporting

PES computes eight different scores to summarize the condition of a pavement section. These scores represent an average condition for each section. Each score is a function of one or more variables, as shown in the table below. The purpose of the variety of scores is to allow flexibility in prioritizing pavement sections in terms of relative need. One District may place greater emphasis on ride quality while another may place emphasis on both visual condition and ride. Still another may feel that some structural information is vital to the prioritization process.

SCORES	VARIABLES							
	ADT	ESALS	F CLASS	FRICTION	CLIMATE	DISTRESS	RIDE	DEFLECTION
Serviceability Index (SI)							X	
Structural Strength Index (SSI)		X			X			X
Skid Number (SN)				X				
Unweighted Visual Utility (UVU)						X		
Adjusted Visual Utility (AVU)					X	X		
Weighted Visual Utility (WVU)	X	X			X	X		
Unadjusted Pavement Score (UPS)						X	X	
Pavement Score (PS)	X	X	X		X	X	X	

ADT -- Average Daily Traffic.
ESALS -- Applied loads converted into an equivalent number of single axle loads (18,000 lbs).
F CLASS -- Functional Classification, relative importance of pavement section to overall highway network.
CLIMATE -- Average annual rainfall and number of freeze/thaw cycles, by county.

The Annual Report addresses the following scores:

1.	**Unweighted Visual Utility (UVU) - Distress Score**
2.	**Serviceability Index (SI)- Ride Quality Score**
3.	**Unadjusted Pavement Score (UPS) - Condition Score**
4.	**Pavement Score (PS) - Rehab Priority Score**
5.	**Structural Strength Index (SSI)**

All charts and tables use data extrapolated from the random statistical sample and are applied to the total mileage of each District. **Analysis of extrapolated results obtained from the statistical sample and a 100 percent survey indicate few differences.**

Unweighted Visual Utility (UVU) -- Distress Score

UVU is a function of the surface distresses found on the pavement section (such as rutting, cracking, failures, and spalled cracks, etc.). The values for UVU range from 1 (worst condition -- most distress) to 100 (best condition -- least distress). The following categories are used to describe the Distress score:

UVU	CLASS	DESCRIPTION
90-100	"A"	VERY GOOD -- Little or no distress
80-89	"B"	GOOD -- One or two slight distresses
70-79	"C"	FAIR -- Multiple distress types, or one severe distress
60-69	"D"	POOR -- Multiple distress types with at least one severe distress
1-59	"F"	VERY POOR -- Combination of moderate and severe distresses

A Distress score value below 80 indicates problems. This problem may be caused by multiple distresses (such as rutting and alligator cracking) or by one severe distress (such as deep rutting). UVU may be used to assist in determination of current maintenance and rehabilitation needs.

Serviceability Index (SI) -- Ride Quality Score

Serviceability Index models the travelling public's perception of roughness found on Texas' highways. SI is a product of a panel rating performed a number of years ago on a selected set of pavement sections having various roughness levels. The Ride Quality score ranges from 0 (for a very rough pavement) to 5 (for a very smooth pavement). The table below identifies the classes of ride quality:

SI	CLASS	DESCRIPTION
4.0-5.0	"A"	VERY SMOOTH PAVEMENT
3.0-3.9	"B"	SMOOTH PAVEMENT
2.0-2.9	"C"	MODERATELY ROUGH PAVEMENT
1.0-1.9	"D"	ROUGH PAVEMENT
0-0.9	"F"	VERY ROUGH PAVEMENT

The minimum desirable value for SI in this report is 3.0. Roads can have a lower ride depending on other factors. This score may also be used to determine current maintenance and rehabilitation programs.

Unadjusted Pavement Score (UPS) -- Condition Score

UPS is calculated from a section's distress and ride quality. The score values range from 1 (worst condition) to 100 (best condition). This score does not consider such factors as climate, traffic, or functional class. Highways are classified by pavement condition, as shown below:

UPS	CLASS	DESCRIPTION
90-100	"A"	VERY GOOD
70-89	"B"	GOOD
50-69	"C"	FAIR
35-49	"D"	POOR
1-34	"F"	VERY POOR

A condition score below 50 indicates a need for major rehab or reconstruction.

Pavement Score (PS)-- Rehab Priority Score

PES uses the PS to prioritize a section's need for rehabilitation based on the following factors: surface distress, ride quality, climate (average county rainfall and average county freeze/thaw cycles), traffic (ADT and 18-k ESALs), and functional class. This score can help in determining what action should be taken, as suggested by the following table:

PS	CLASS	PRIORITY		
		Preventive Maintenance	Routine Maintenance	Rehab/ Reconstruction
90-100	"A"	HIGH	N/A	N/A
70-89	"B"	HIGH	LOW	N/A
50-69	"C"	MODERATE	HIGH	LOW
35-49	"D"	LOW	MODERATE	MODERATE
1-34	"F"	N/A	N/A	HIGH

The values for PS range from 1 (urgent need for rehab) to 100 (no rehab needed). A PS below 50 indicates that some action besides preventive maintenance should be taken. D-18PM and some Districts use PS to determine rehab and maintenance needs.

Structural Strength Index (SSI)

This score is based on deflection data acquired from the FWD. SSI is not a factor in any other PES score, but is used to indicate a pavement's structural integrity. The values for SSI range from 1 (for a very weak pavement) to 100 (for a very strong pavement). SSI is grouped into the following categories to describe a pavement's structural integrity.

STRUCTURAL STRENGTH INDEX	CLASS
70-100	STRONG
40-69	MODERATE
1-39	WEAK

A SSI below 70 indicates that the pavement could deteriorate rapidly, even if the pavement surface is in good condition, and should be closely monitored.

Skid Number (SN)

The skid number is calculated from the following equation:

$$SN = 100f$$

f is a friction factor from a locked-wheel skid test performed by a trailer equipped for wet-skid testing. Skid resistance testing is in accordance with the American Society of Testing and Materials (ASTM) method E274, which specifies the tire, speed, temperature, water film thickness, and other conditions. The measurement does not directly indicate the stopping characteristics of any one vehicle, driver, or climatic condition. However, it is useful in maintenance planning, evaluating various materials and construction methods. The Skid number is generally an indicator of the need for some surface treatment to improve friction such as a seal coat, or strip seal. Skid resistance testing is not analyzed in this report, but the table below is a useful reference for interpreting SN.

SN	CLASS	DESCRIPTION
65-100	EXCELLENT	VERY COARSE CHIP SEAL (seldom attained)
50-64	VERY GOOD	COARSE CHIP SEAL OR HIGH QUALITY SURFACE
35-49	GOOD	TYPICAL ASPHALT OR CONCRETE SURFACE
20-34	FAIR	WORN, POLISHED OR BLEEDING SURFACE
0-19	POOR	HIGHLY POLISHED OR BADLY BLEEDING SURFACE

PES at this time does not mandate skid testing on any pavements. Skid testing is voluntary and is left to the discretion of each District.

CHAPTER 2
1986 THROUGH 1990 PES SURVEYS

PES estimates are based on a statistical sample of the state-maintained highway system. Samples are used to minimize the amount of time spent collecting data. In 1990, the PES program randomly selected 100 percent of the Interstate (IH) mileage, 50 percent of US and State highway (SH) mileage, and 20 percent of the Farm-to-Market (FM) mileage. This resulted in a sample size of 33,315 mainlane miles in 1990 (for visual and ride).

Table 2.1 lists the total length of roadway mileage evaluated from 1986 to 1990, by pavement type (ACP, CRC, and JCP) and highway system (IH, US, SH, and FM). Table 2.2 lists the percentage of roadway mileage evaluated from 1986 to 1990, by pavement type and highway system. Due to conversion to the Texas Reference Marker (TRM) system in 1990, the numbers in this report vary slightly from the 1989 Annual Report.

TABLE 2.1 -- Total Length of Roadway Mileage Evaluated From 1986-1990.
PES Random Statistical Sample Sections Only.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	TOTAL
1986	ACP	4,417	8,090	8,705	7,525	28,737
	CRC	1,298	437	204	4	1,943
	JCP	130	255	319	33	737
	TOTAL	5,845	8,782	9,228	7,562	31,417
1987	ACP	4,471	6,747	7,230	7,765	26,213
	CRC	1,087	129	66	2	1,283
	JCP	143	82	97	16	338
	TOTAL	5,701	6,958	7,393	7,783	27,834
1988	ACP	4,459	7,454	8,144	7,781	27,433
	CRC	1,095	370	242	0	1,707
	JCP	168	255	243	11	678
	TOTAL	5,722	8,080	8,629	7,386	29,818
1989	ACP	4,597	4,572	5,954	7,281	22,403
	CRC	1,200	109	46	12	1,367
	JCP	187	51	86	6	330
	TOTAL	5,984	4,732	6,086	7,299	24,100
1990	ACP	4,668	8,367	8,709	9,189	30,934
	CRC	1,261	293	168	12	1,734
	JCP	228	216	189	14	647
	TOTAL	6,157	8,877	9,066	9,215	33,315

NOTE: Values may vary from previous annual reports due to Texas Reference Marker System conversion difficulties.

TABLE 2.2 -- Percentage of Roadway Mileage Evaluated From 1986-1990.
PES Random Statistical Sample Sections Only.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	TOTAL
1986	ACP	96.91%	58.47%	58.73%	19.06%	39.28%
	CRC	98.92%	92.75%	76.15%	52.78%	93.68%
	JCP	81.31%	80.39%	83.88%	13.82%	75.79%
	TOTAL	96.10%	60.41%	59.91%	19.07%	41.76%
1987	ACP	98.68%	50.26%	50.05%	19.53%	36.42%
	CRC	98.33%	22.96%	27.08%	5.41%	71.06%
	JCP	87.68%	19.12%	26.18%	10.60%	41.53%
	TOTAL	97.77%	48.39%	48.91%	19.48%	37.50%
1988	ACP	98.53%	56.15%	56.05%	18.81%	38.53%
	CRC	94.80%	79.55%	73.95%	14.81%	87.47%
	JCP	90.93%	80.00%	66.27%	15.23%	72.14%
	TOTAL	97.16%	57.68%	56.78%	18.79%	40.68%
1989	ACP	98.78%	33.96%	39.79%	18.21%	30.54%
	CRC	99.66%	24.01%	25.16%	42.86%	72.42%
	JCP	98.37%	14.25%	19.57%	13.04%	37.77%
	TOTAL	98.96%	33.03%	38.91%	18.22%	31.92%
1990	ACP	98.34%	60.58%	58.74%	23.45%	42.51%
	CRC	99.20%	64.08%	71.04%	22.73%	86.86%
	JCP	97.59%	70.80%	67.90%	20.45%	72.46%
	TOTAL	98.51%	61.00%	59.15%	23.44%	44.36%

NOTE: Values may vary from previous annual reports due to Texas Reference Marker System conversion difficulties.

-Notes-

CHAPTER 3
AUDIT OF PES DATA

Each year, an audit is performed to verify consistency and accuracy of data collection practices between Districts. District personnel collect the audit data by rating randomly selected sections from the mandatory PES sections of a neighboring District. These sections are called audit sections. These audit sections are used to compare the variability in ratings between teams on the same sections. The audit sample size is kept small, about five percent, so that the audit can be completed in one work week. The sample for the three pavement types (ACP, CRC, and JCP) are selected separately so that are representative.

Ideally, since the same area of roadway is rated, the Distress score computed from regular and audit data should be identical. Actually, the rating procedure is subjective and different distress ratings by different teams occur. The ratings precision (or "repeatability") influence the reliability of the PES scores.

Reliability of Statewide Distress Scores

The 1990 audit data analysis summarized in Table 3.1, indicates a 79.5 percent probability that distress scores returned by different teams on the same section will be within 15 points of each other. This compares with 77.5, 75.0, 72.5, and 82.2 percent for 1986, 1987, 1988, and 1989, respectively.

TABLE 3.1 -- Precision of PES Distress Scores.

PAVEMENT TYPE	1986	1987	1988	1989	1990
ACP	77.2	74.2	71.7	80.8	79.3
CRC	87.2	83.6	89.5	91.2	79.4
JCP	60.0	76.9	62.5	80.0	80.6
ALL	77.5	75.0	72.5	82.2	79.5

NOTE: Values indicate the probability that distress scores from different rating teams will be within 15 points of each other.

Reliability of Individual Distresses

The PES audit results are used to analyze individual distress reliability. This reliability is based on the distress utility factor and rating precision. The utility factor is the weight each distress has on the PES scores (UVU, UPS, PS and etc.). An example is alligator cracking will reduce a PES score more than rutting. Rating precision is the repeatability between audit and District data for each distress. An example the one team rates a distress in the 1 to 10 percent category and the other team rates the distress on the same section in the 11 to 50 percent category.

These two factors combined determine determines the probability of a distress causing a 10-point Distress score difference (eg from 80 to 70, or 45 to 35). Table 3.2 shows the reliability for each distress of the three pavement types. Any error in the Distress score is also reflected in the Condition score (UPS) and Rehab Priority score (PS)

TABLE 3.2 -- Reliability of PES Distress Ratings.

PAVEMENT TYPE	DISTRESS TYPE	PROBABILITY OF 10-POINT DIFFERENCE IN DISTRESS SCORE				
		1986	1987	1988	1989	1990
ACP	Rutting	9.2	14.0	13.3	10.3	12.5
	Patching	11.0	11.0	10.3	8.8	8.0
	Failures	6.3	7.9	6.2	4.0	4.3
	Block Cracking	3.8	2.8	3.6	1.5	2.2
	Alligator Cracking	16.9	13.3	13.2	8.2	9.5
	Longitudinal Cracking	7.2	8.7	7.3	6.9	6.2
	Transverse Cracking	8.1	10.2	9.6	5.4	5.8
CRC	Spalled Cracks	6.4	0.0	0.0	0.0	1.2
	Punchouts	12.8	1.8	0.0	0.0	8.5
	Asphalt Patches	8.5	1.8	5.3	2.0	1.2
	Concrete Patches	4.2	21.8	8.8	9.8	15.8
JCP	Failed Joints/Cracks	33.3	23.1	31.3	13.3	16.3
	Failures	33.3	7.7	29.27	20.0	15.1
	Shattered Slabs	6.7	0.0	0.0	0.0	0.0
	Slabs with Longitudinal Cracks	6.7	0.0	0.0	0.0	1.1
	Concrete Patches	6.7	0.0	14.6	0.0	5.9

Note: Shaded areas indicate distress types which will most likely cause a 10-point difference in Distress Score.

Analysis of the Reliability of Statewide Distress Scores

As shown in Table 3.2, PES distress rating reliability worsened slightly in 1990 for all pavement types. Rutting measurements continued to be the least repeatable distress type for ACP. On CRC, concrete patches was the least precise while failed joints/cracks and failures continued to be the least precise on JCP.

Overall the precision of the PES scores dropped 2.7 percent from 82.2 percent in 1989 to 79.5 percent. This drop in precision can attributed to CRC and ACP ratings. CRC ratings fell 11.8 percent to 79.4 percent, while ACP went down from 80.8 percent in 1989 to 79.3 percent. The JCP precision increased slightly from 80.0 percent to 80.6 percent.

Calibration and Verification of Ride Quality Equipment

For the 1990 PES data collection year, the Department maintained and operated 17 Response Type Road Roughness Meters (RTRRMs), known as SIometers, or Walker Roughness devices. Each year, all SIometers calibration must be checked. This process is intended to ensure that: 1) Each SIometer provides uniform pavement roughness measurements when repeatedly operated over the same section, 2) All SIometers provide similar results on the same section , and 3) All SIometers provide consistent results form year to year. Pavement sections used in the calibration process are 0.2 miles in length and cover a roughness range from very smooth to very rough.

To obtain a reference roughness, a section is measured by the Profilometer. The Profilometer is a vehicle which provides an estimate profile of the left and right wheelpaths for a section. The results obtained are comparable to a rod and level survey. From this profile measurement, a reference Serviceability Index (SI) is calculated. Once the reference SI is obtained, each SIometer is driven over each test section five times. The results are averaged and compared to the reference SI. Each SIometer is then adjusted to conform to the reference SI.

In 1989, nine test sections were used for calibration. After review of the ride data that year, it was determined that nine sections was too small of a sample to achieve desired effect. As a result, fourteen section were utilized in the 1990 calibration.

Calibration and Verification of Deflection (Structural) Equipment

The Department operated 13 automated deflection measuring devices (Falling Weight Deflectometers, or FWDs) for the collection of structural data in 1990. To determine the FWDs accuracy, a comparison test was conducted in Austin in December 1990. This test, included all FWDs and used several different pavement structures. The test indicated that pavement deflections variability due to pavement factors concealed the individual FWD variability. For example, pavement deflections change dramatically because of load plate position. Small plate positioning errors yield deflections difference on the order of five to ten times that obtained by switching FWDs and testing the same spot. This situation is similar one in which a ruler marked to the nearest foot is used to measure object to the nearest inch. However during this time minor equipment adjustments were performed to ensure correct data collection, to the extent possible. This calibration problem is being addressed. The DOT has been selected as the Strategic Highway Research Program (SHRP) FWD calibration center for the Southeast region . In addition, a DOT research project is developing a calibration system for field use.

Calibration and Verification of Surface Friction (Skid) Equipment

The Department currently operates five locked-wheel skid units and is building two more units for surface friction data collection. To assure correct data collection a static and dynamic calibration of all skid units are performed yearly. A skid unit and the static calibration force plate are sent to the Texas Transportation Institute (TTI) for operation characteristics verification and calibration. The static calibration of the other system is done using the force plate. The TTI-calibrated skid unit is used to establish reference sections around the Austin area for the dynamic calibration of the other units.

Field verification of the static and dynamic calibration are done each day before data collection. The static calibration is verified by a torque arm and known weight. Dynamic calibration is checked by skidding sections located close to the data collection sites and checking them daily. When a unit is found to be out of calibration it is returned to Austin for re-calibration.

CHAPTER 4
CONDITION OF TEXAS PAVEMENTS

The condition of Texas highways is determined by analyzing the annual PES survey data. In Texas, ride quality and surface distress are used as the pavement condition primary indicators. Therefore the overall network condition is based upon the unadjusted pavement score (UPS), referred to as Condition score.

Condition score is a uniform measure of pavement condition across the State, as this score is not weighted by regional factors such as climate, traffic, and material properties. This score presents the engineer with the average driver's perception of the pavement surface.

This chapter presents the pavement condition of the four highway systems and three pavement types. Ride quality and surface distress are further presented to assist understanding pavement condition components. All charts are based on the PES random statistical sample which represents the entire Texas highway network.

-Notes-

CONDITION OF THE STATEWIDE NETWORK

Statewide pavement condition is based upon UPS and is divided into five different classes as indicated in Table 4.1. The statewide distribution of UPS in these classes is shown in Figure 4.1 depicting the trends in pavement condition of the Texas highway network from 1986 to 1990. This figure indicates an increase in overall pavement condition each year from 1986 to 1989 with a slight decline in 1990. The main change in 1990 was in class "A" mileage which decreased from 66.2 percent in 1989 to 63.9 percent. All other categories increased, with "B" rated mileage increasing the most.

The reason for the decline in statewide condition in 1990 can be attributed to both ride quality and pavement distress. Ride quality had a large shift of class "A" mileage to class "B" in 1990, as shown in Figure 4.2. This was expected because the 1989 roughness survey caused an increase in the number of "very smooth" PES sections. D-18PM determined that too few calibrating sections were used for the equipment. Chapter 3 provide a more complete description. Ride quality is examined separately in a later section of this chapter.

Pavement distress also had an influence in the overall decline of statewide pavement condition. In 1990, class "A" mileage decreased to 67.8 percent. This was a 1.2 percent change when compared to 1989. Categories "B","C", and "D" all increased in mileage, while class "F" mileage decreased by 1.0 percent to 7.3 percent. Figure 4.3 indicates the change in pavement distress for the last five years. More information on pavement distress is contained in a later section of this chapter.

TABLE 4.1 -- Classes of Condition Score.

UPS	CLASS	DESCRIPTION
90-100	"A"	VERY GOOD
70-89	"B"	GOOD
50-69	"C"	FAIR
35-49	"D"	POOR
1-34	"F"	VERY POOR

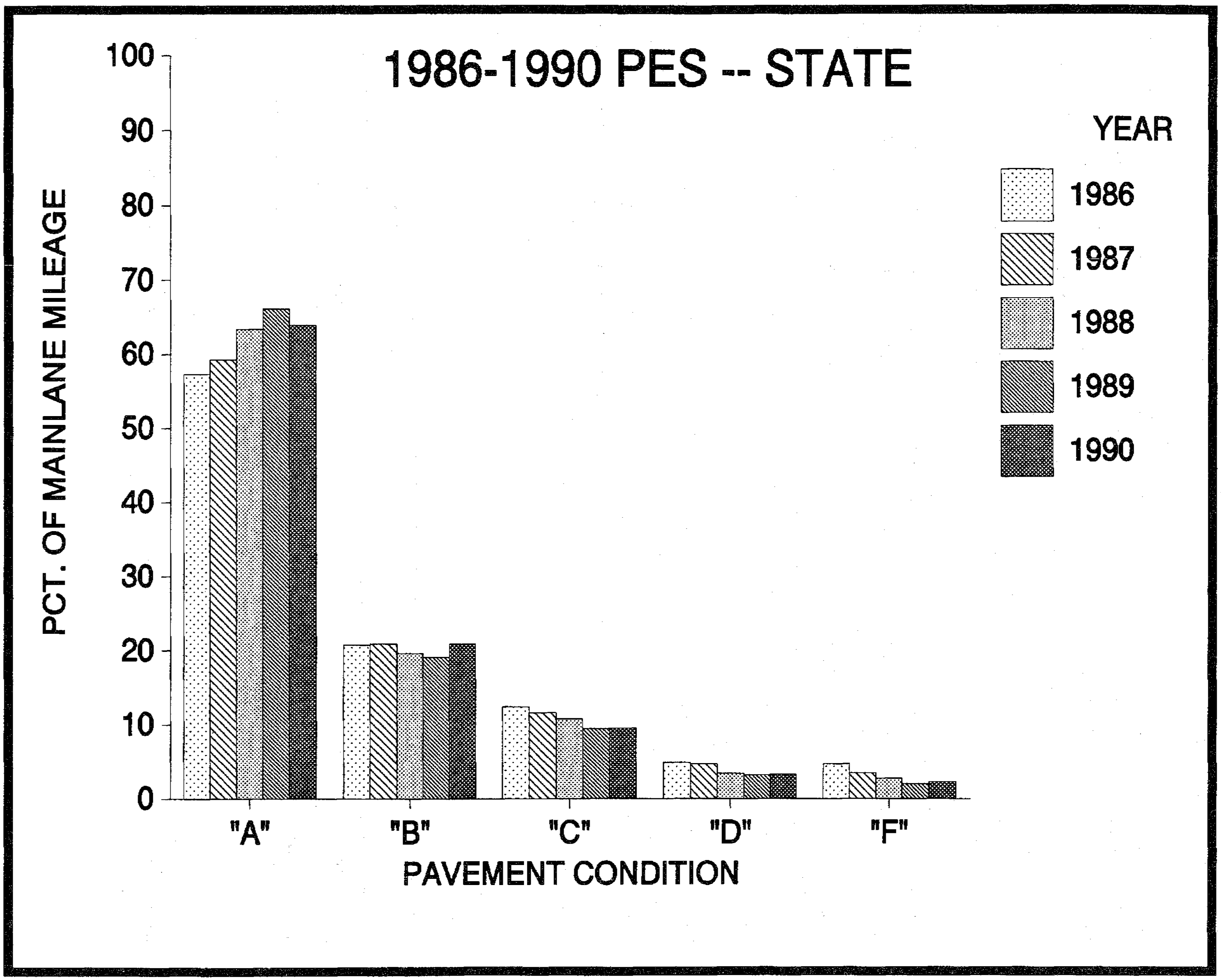


Figure 4.1 -- Condition of Texas Highway Network 1986-1990.
(Frontage roads are not included in this chart.)

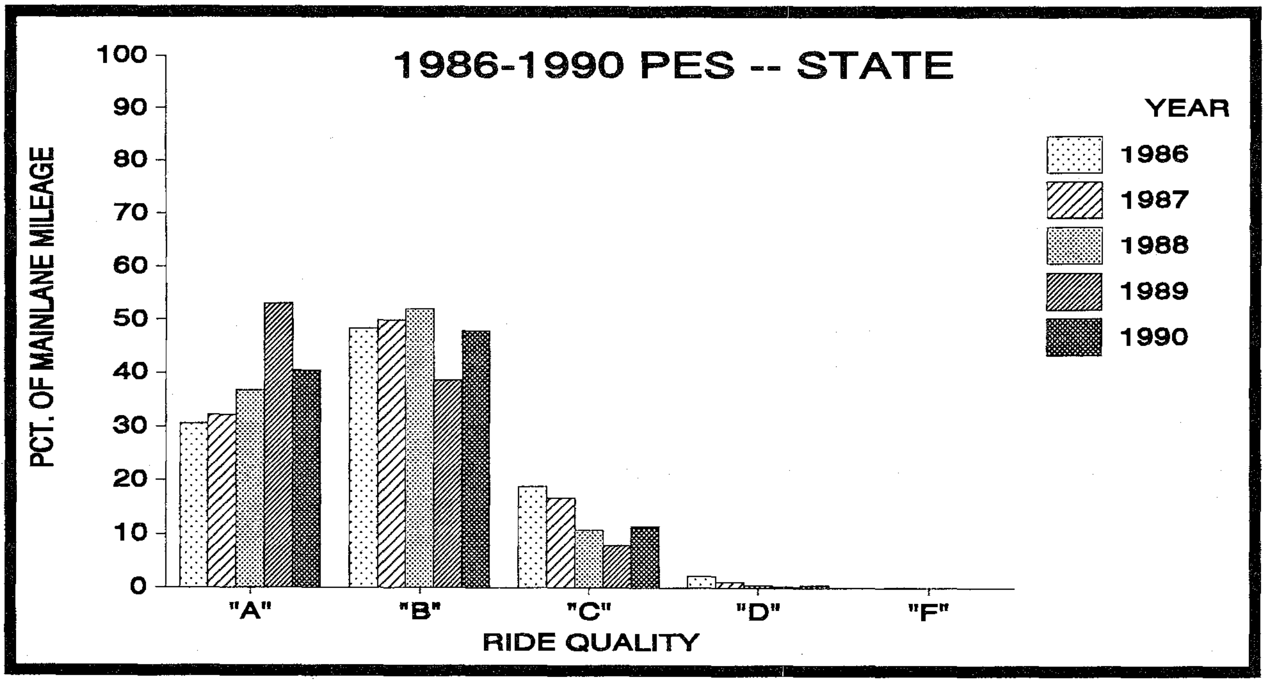


Figure 4.2 -- Ride Quality of Texas Highway Network 1986-1990.

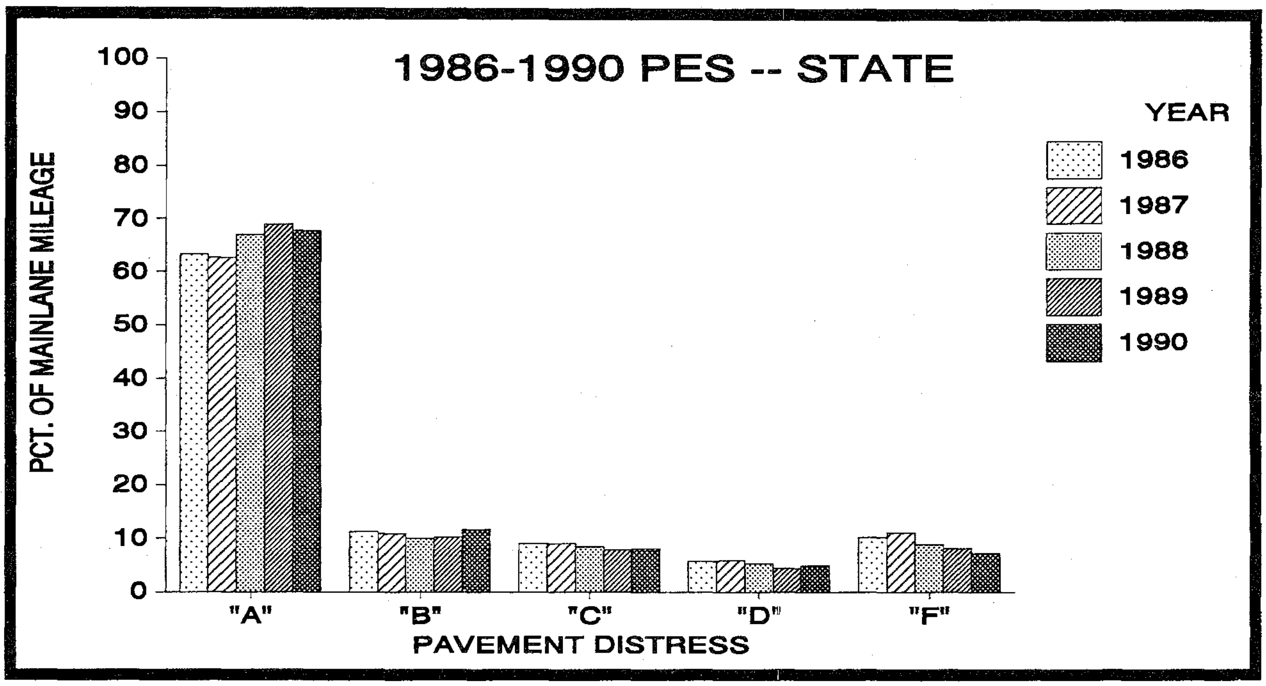


Figure 4.3 -- Pavement Distress of the Texas Highway Network 1986-1990.

Condition of IH System

In 1990, the overall condition of the IH system decreased for the second year in a row, Figure 4.4. Class "A" mileage was down slightly from 71.2 percent in 1989 to 70.5 percent in 1990. Classes "D" and "F" categories rose to 5.7 percent of the rated mainlane mileage. The PES data indicates the IH system's condition peaked in 1988, and has been slowly declining since then. The IH system consists of all three pavement types. In the last three years ACP has remained in fairly stable condition, while CRC peaked in 1988 and has declined each year. In 1990, JCP showed a big gain in good and very good mileage and a decline in very poor mileage. The main contributor to the decline of the IH system has been CRC mileage.

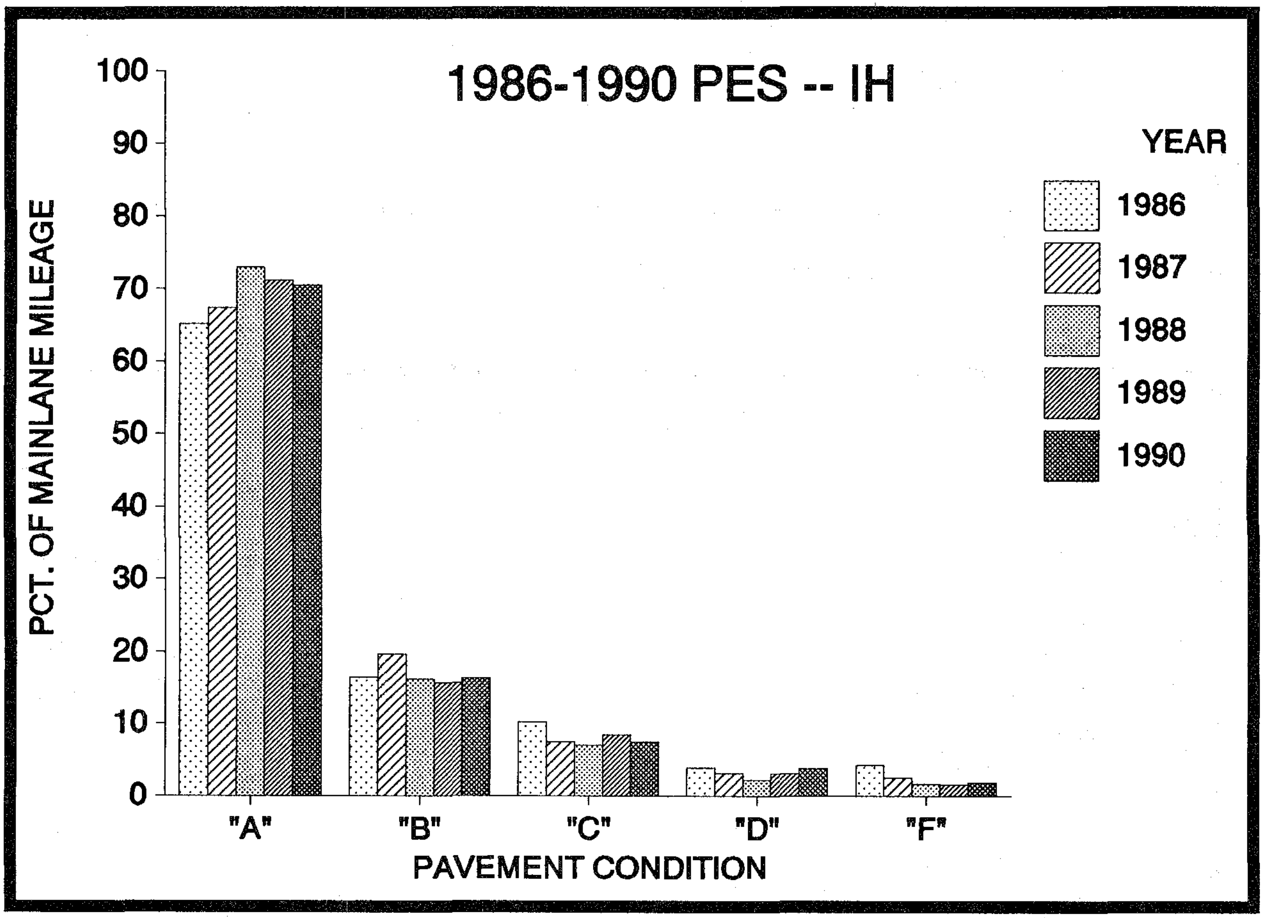


Figure 4.4 -- Condition of IH System 1986-1990.

Condition of US System

The US highway system's condition in 1990 declined to the 1988 level. Very good mileage made up 64.7 percent of system, down 4.1 percent from 1989. Overall ride quality decreased on the system and pavement distress increased slightly. The US system is made up of all three major pavement types. ACP is the majority pavement type on the US system and in 1990, declined in condition to 1988 levels. CRC mileage on the system declined in condition, being in its worst state since 1987. JCP condition also decreased in 1990 to below 1987 levels. Figure 4.5 indicates condition trends from 1986-1990.

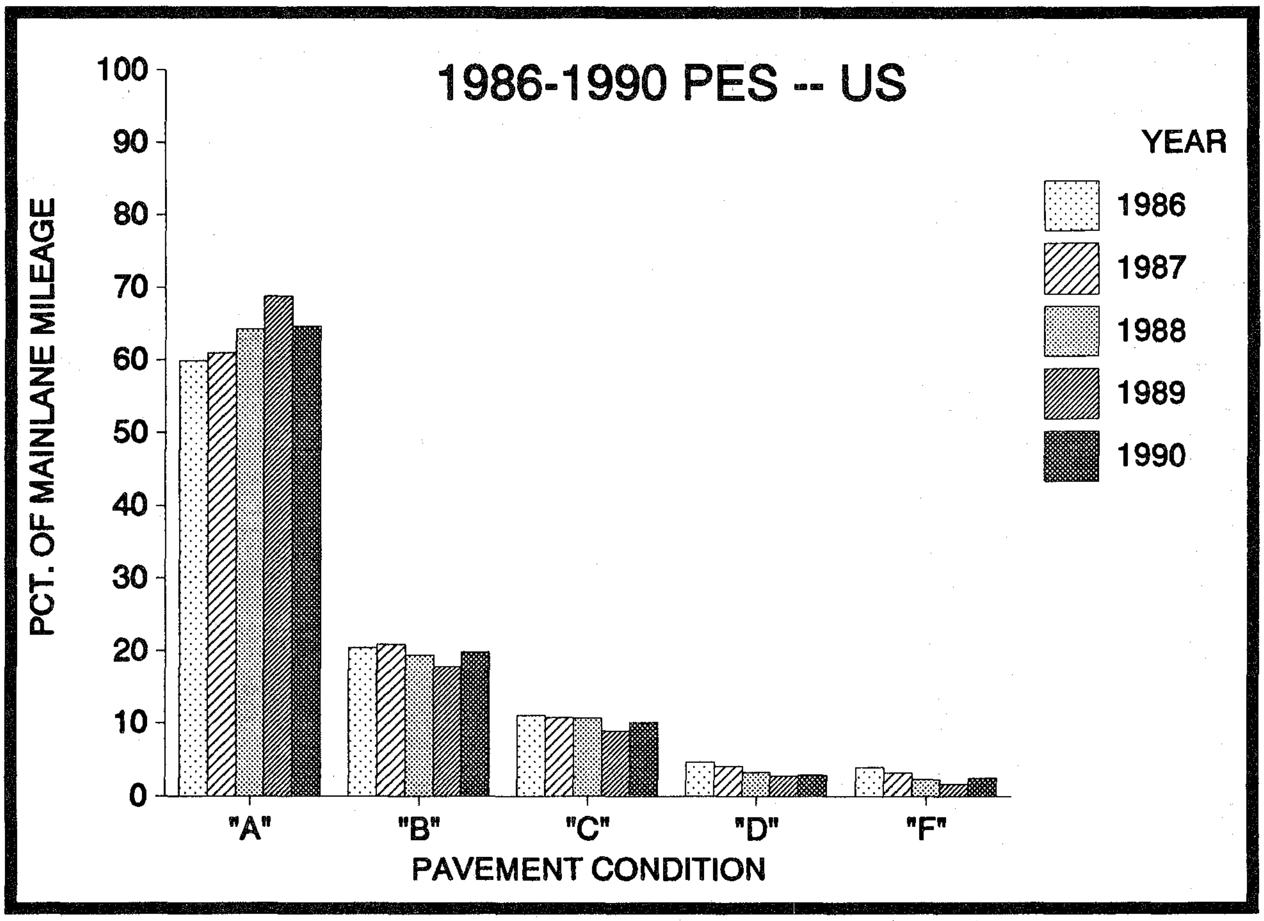


Figure 4.5 -- Condition of US System 1986-1990.

Condition of SH System

The SH system in 1990 decreased in overall condition when compared to 1989, but was in slightly better shape than 1988. Pavement distress increased slightly in 1990, while ride quality shifted from very good to the good categories. The SH system is similar to the US system having all three major pavement types, with ACP being the majority of the mileage. ACP mileage in 1990 had a slight decrease in very good mileage, but poor and very poor mileage also decreased. CRC on the system was at its lowest level in the last five years. JCP condition was also at a five year low. Rigid pavements have little effect on the overall condition, because of their low mileage.

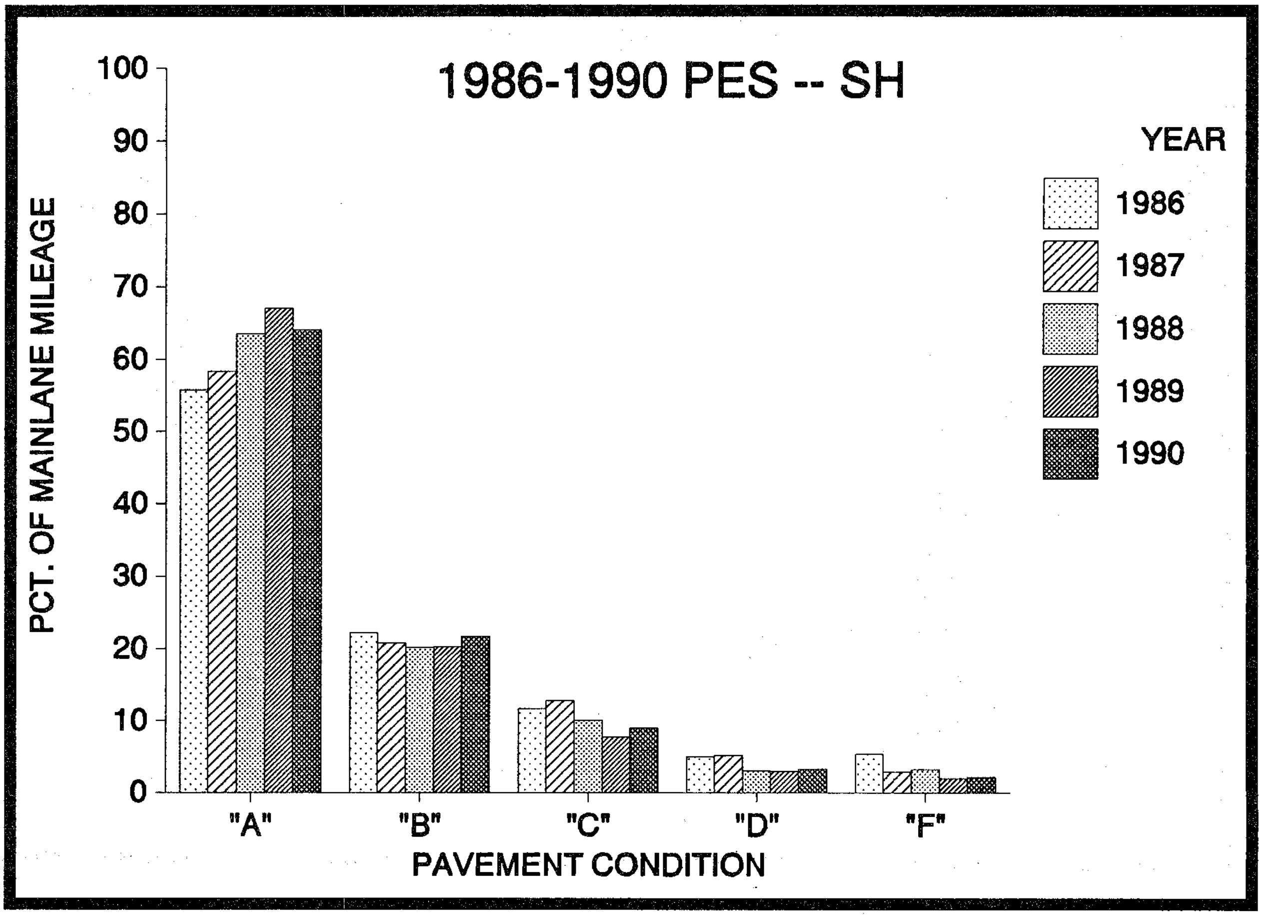


Figure 4.6 -- Condition of SH System 1986-1990.

Condition of FM System

The 1990 overall condition of the FM highway system decreased slightly from 1989, with a 1.0 percent drop in class "A" mileage. Pavement distress did not increase, but ride quality did and was affected by the 1989 survey. ACP makes up nearly all of the FM system, and as expected shows the same trends. Figure 4.7 indicates the FM system trends in condition from 1986-1990.

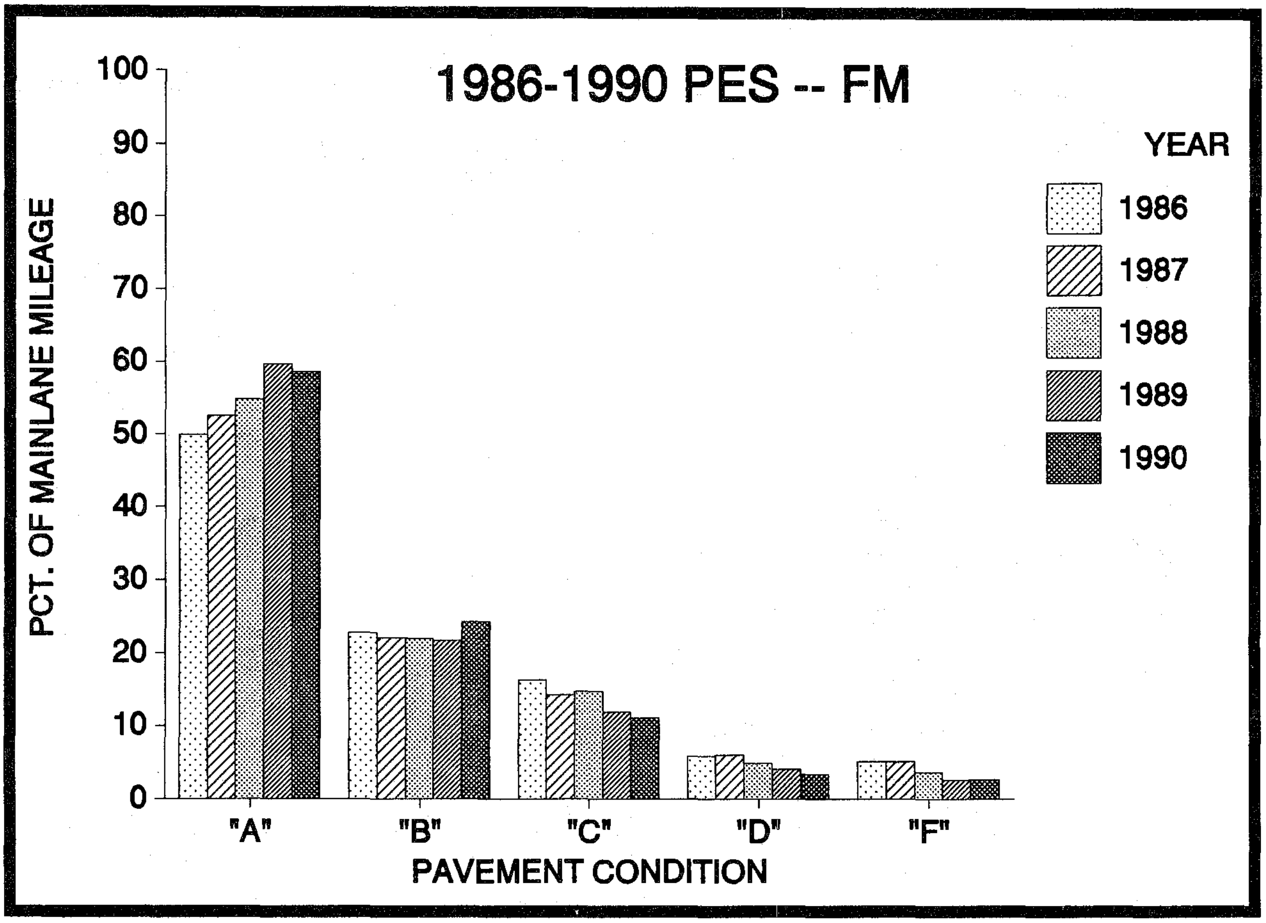


Figure 4.7 -- Condition of FM System 1986-1990.

Asphalt Pavement (ACP) Condition

In 1990, ACP's overall condition declined slightly, with class "A" mileage down from 67.4 percent in 1989 to 65.6 percent. Class "B" mileage was up slightly at 21 percent while all other classes remained at the same level. ACP on each of the four major highway systems also indicated a slight decline in 1990. Even with the decrease in condition ACP was in slightly better shape than in 1988. Pavement distress increased while ride quality again had a large percentage of class "A" mileage shift into class "B". Figure 4.8 shows the trends from 1986-1990.

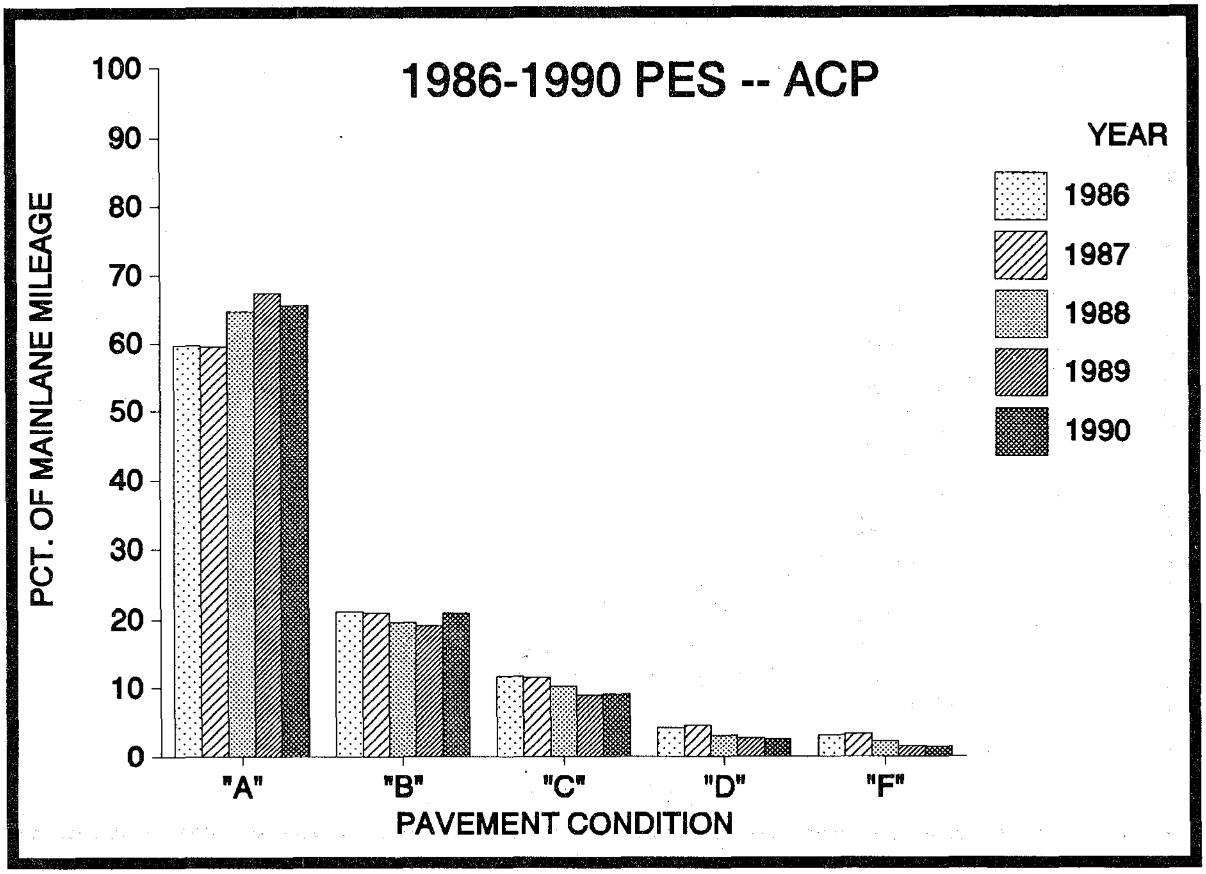


Figure 4.8 -- ACP Condition 1986-1990.

Continuously-Reinforced Concrete (CRC) Condition

The overall condition of CRC declined for the second straight year in 1990. The three major highway systems with CRC (IH, US, and SH) showed a decline in overall condition. Class "A" mileage was at 48.5 percent compare to 54.8 percent in 1989 and 59.5 percent in 1988. Class "D" and "F" mileage was up to 17.9 percent in 1990 compared to 13.8 percent in 1989. Pavement distress remained stable in 1990, therefore the decline in CRC condition is caused by reduced ride quality. Figure 4.9 indicates trends from 1986-1990.

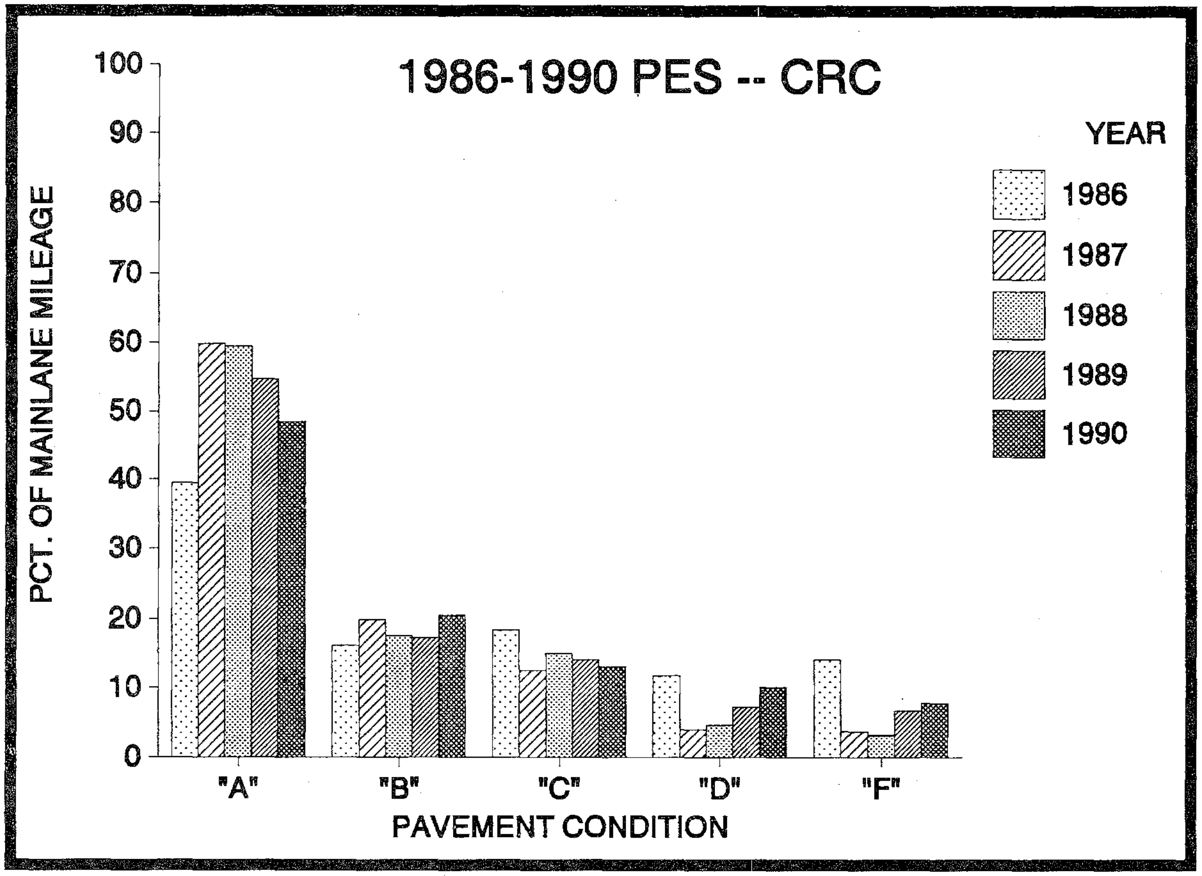


Figure 4.9. -- CRC Condition 1986-1990.

Jointed Concrete Pavement (JCP) Condition

Jointed Concrete Pavement continued to be the pavement type in the worst condition. In 1990, JCP showed a decrease in overall condition. One factor in this decline is the fluctuating sample size for rigid pavements. In 1990, the survey indicated that 21.6 percent of the mileage was in class "A" and 41.8 percent was in classes "D" and "F". This is the worst condition for JCP since 1986. Ride quality and pavement distress both were factors in the decrease in condition. Of the three highway systems which have JCP mileage, the IH system showed some improvement while the US and SH systems declined in condition. Figure 4.10 indicates the trends of JCP from 1986-1990.

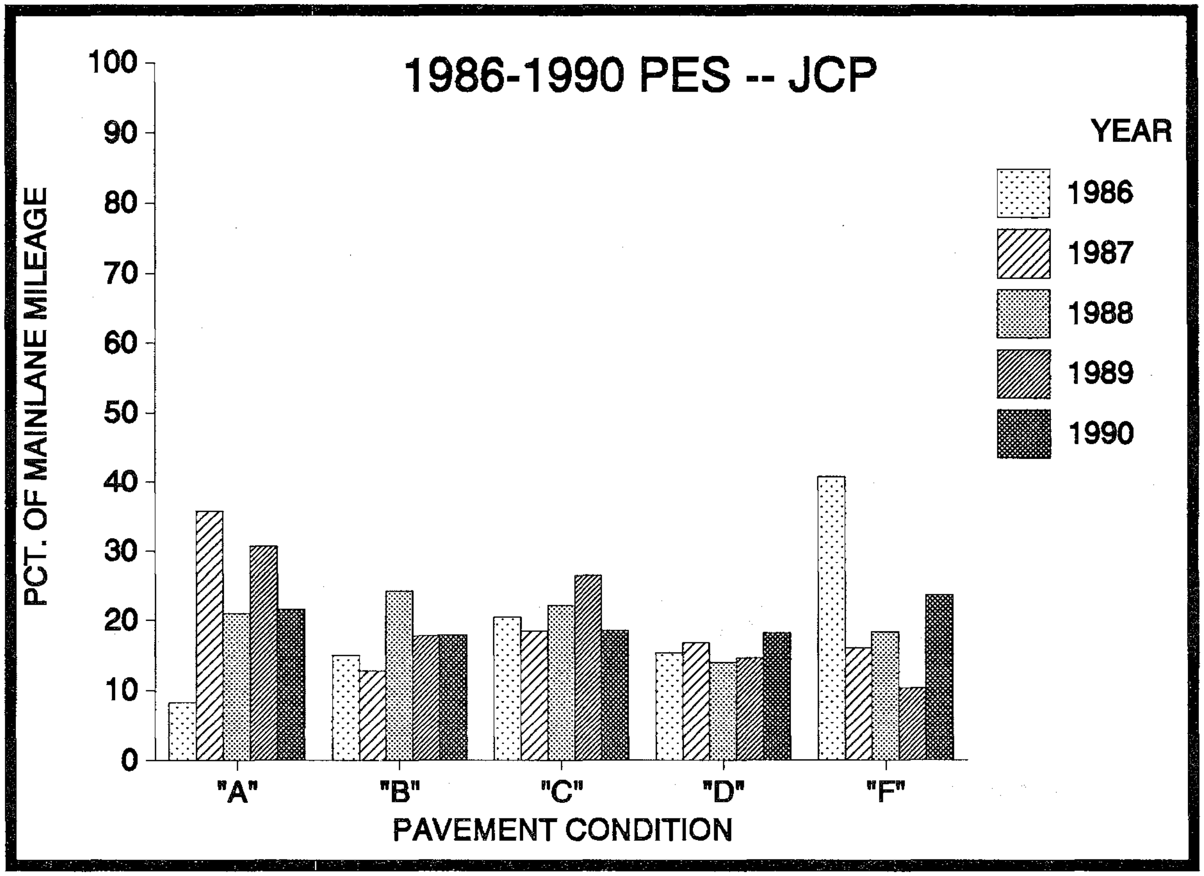


Figure 4.10 -- JCP Condition 1986-1990.

RIDE QUALITY OF THE STATEWIDE NETWORK

Statewide ride quality decreased in 1990 to around the 1988 level, as Figure 4.11 indicates. This was expected because of the ride quality survey in 1989 was overestimate due to equipment calibration problems. This calibration problem is explain in Chapter 3.

The 1990 ride quality survey indicated that 40.4 percent of the mainlane mileage was in the very smooth class, while less than one percent was in the rough to very rough class. All four highway systems and the three pavement types showed a decrease in ride quality when compared to 1989, but were much improved over the 1986 levels. A more detailed look at each highway system and pavement type will follow. A description of the five categories of ride quality are described in Table 4.2 below.

TABLE 4.2 -- Classes of Ride Quality.

SI	CLASS	DESCRIPTION
4.0-5.0	"A"	VERY SMOOTH PAVEMENT
3.0-3.9	"B"	SMOOTH PAVEMENT
2.0-2.9	"C"	MODERATELY ROUGH PAVEMENT
1.0-1.9	"D"	ROUGH PAVEMENT
0-0.9	"F"	VERY ROUGH PAVEMENT

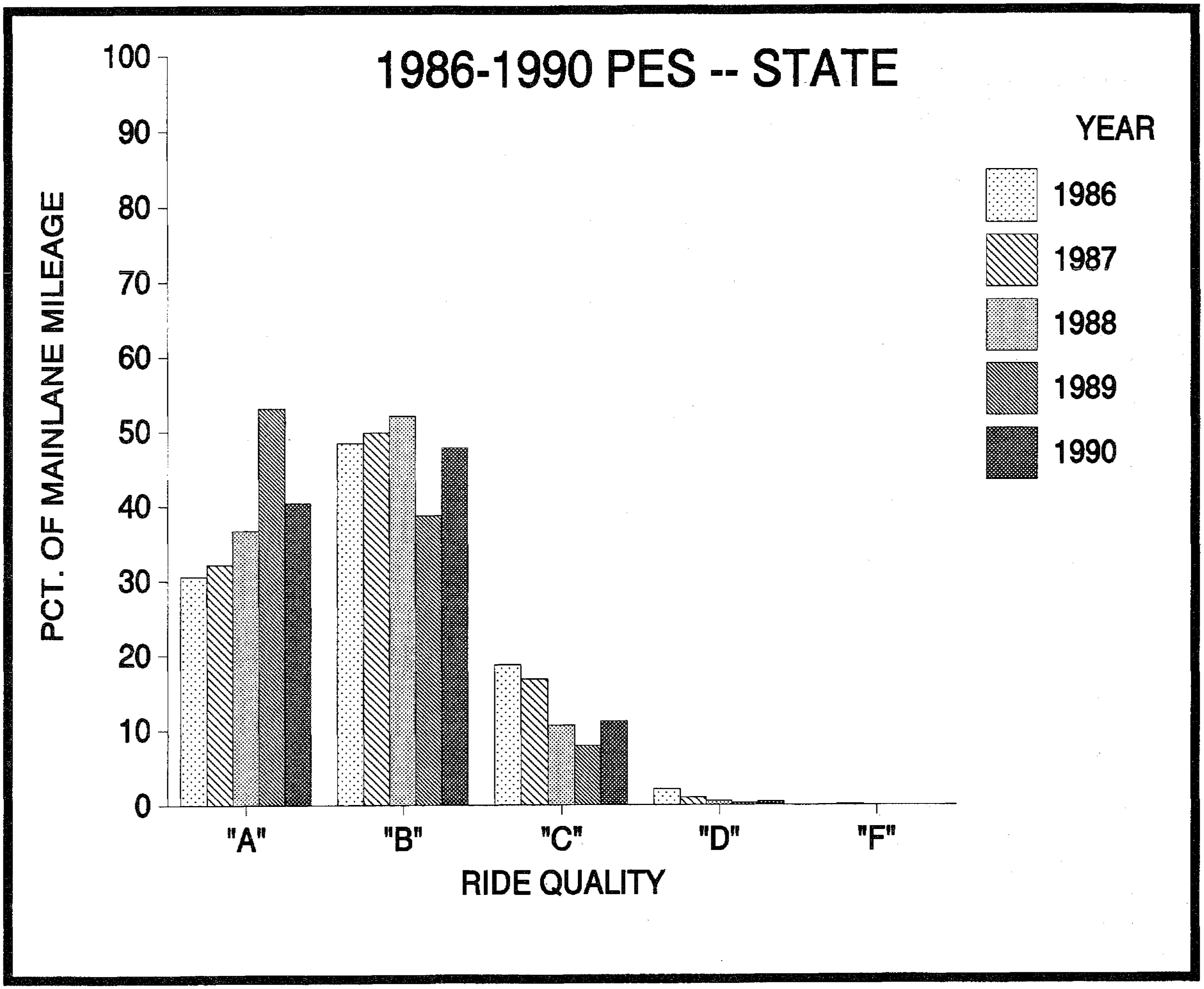


Figure 4.11 -- Ride Quality of Texas Highway Network 1986-1990.

Ride Quality of the IH System

In 1990, 3.6 percent of the IH mainlane mileage had a SI value below 3.0. This was up from the 1988 and 1989 surveys when only 2.0 percent of the mileage had an SI less than 3.0. Very smooth mileage was at 59.8 percent down 12.7 percent, from the 1989 survey. However very smooth mileage was also down when compared to 1988, when 63.0 percent of Interstate mileage had an SI of 4.0 or greater. ACP and CRC increased in mileage with a SI below 3.0, while JCP declined. Overall the Interstate ride quality was the best of the four highway systems and above the statewide average. Figure 4.12 indicates the ride quality distribution from 1986-1990.

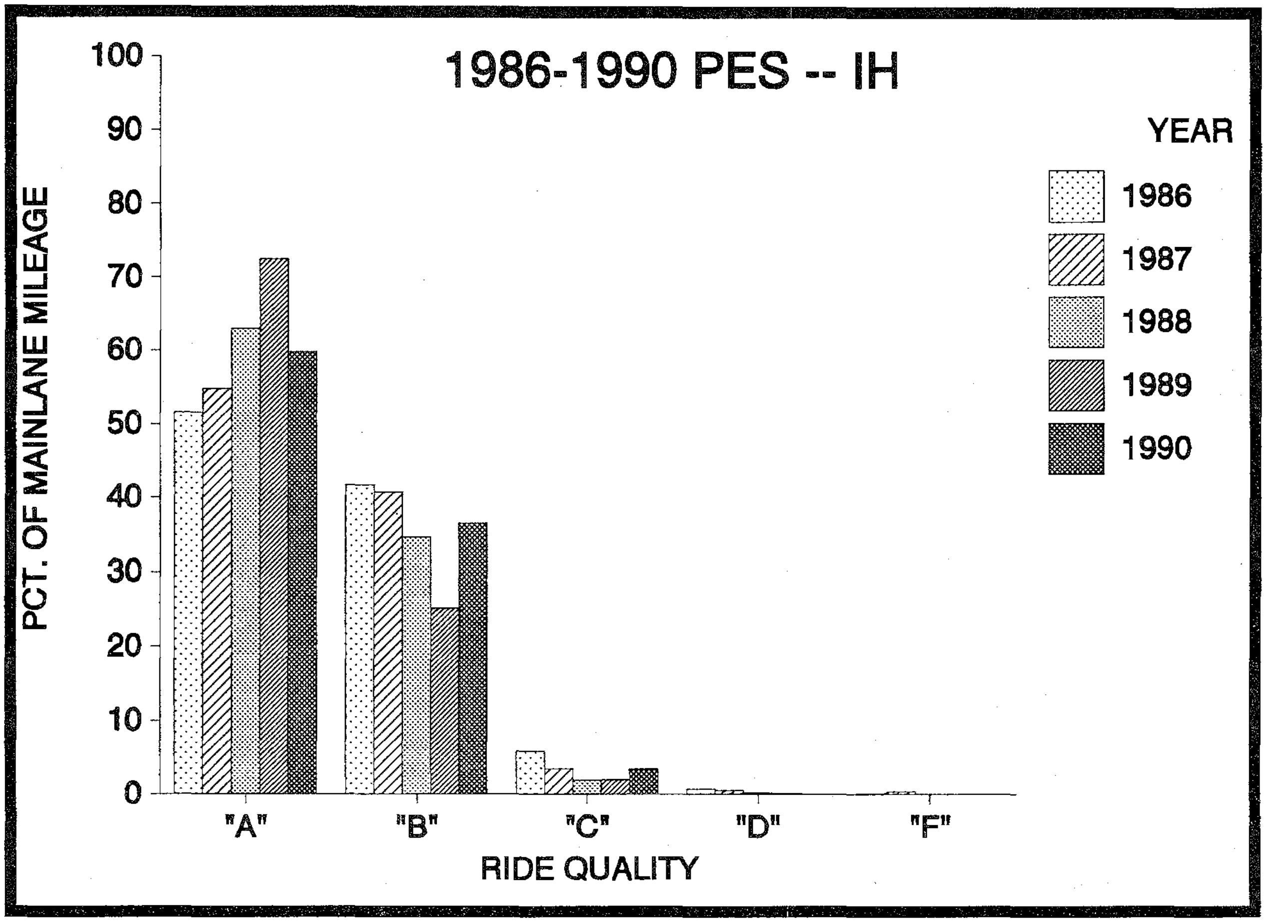


Figure 4.12 -- Ride Quality of IH System 1986-1990.

Ride Quality of the US System

As expected, the US system's overall ride quality dropped in 1990 when compared to 1989, but was still better than the 1988 survey. Mileage with an SI below 3.0 was at 5.4 percent, the same as in 1988. Very smooth mileage was 52.1 percent, the second highest level in the last five years. All three major pavement types were rougher when compared to the 1989 survey, but only ACP had better ride quality than the 1988 survey. When compared to the other highway systems, the US system had the second best ride quality and it too was above the statewide average. Figure 4.13 indicates trends from 1986-1990.

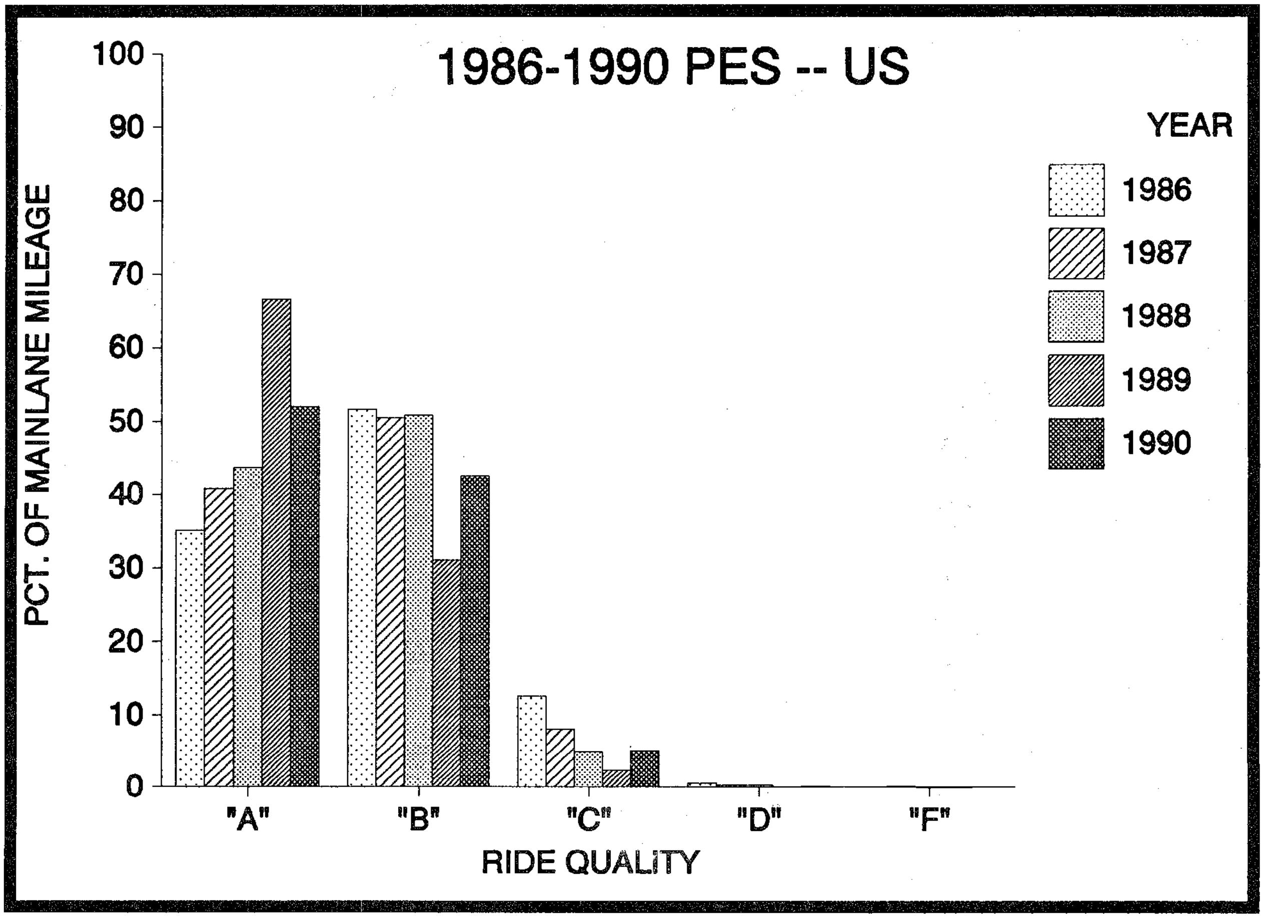


Figure 4.13 -- Ride Quality of US System 1986-1990.

Ride Quality of the SH System

The SH system was rougher overall in 1990, when compared to 1989, but better than in 1988. The amount of mileage below 3.0 was 11.4 percent, while very smooth mileage was at 38.1 percent. If 1989 data were ignored, the SH system would have its best overall ride quality in the last five years. Of the three major pavement types, only ACP did not fall below 1988 levels. The SH system was below the statewide average and was only better than the FM system in ride quality. Figure 4.14 indicates trends from 1986-1990.

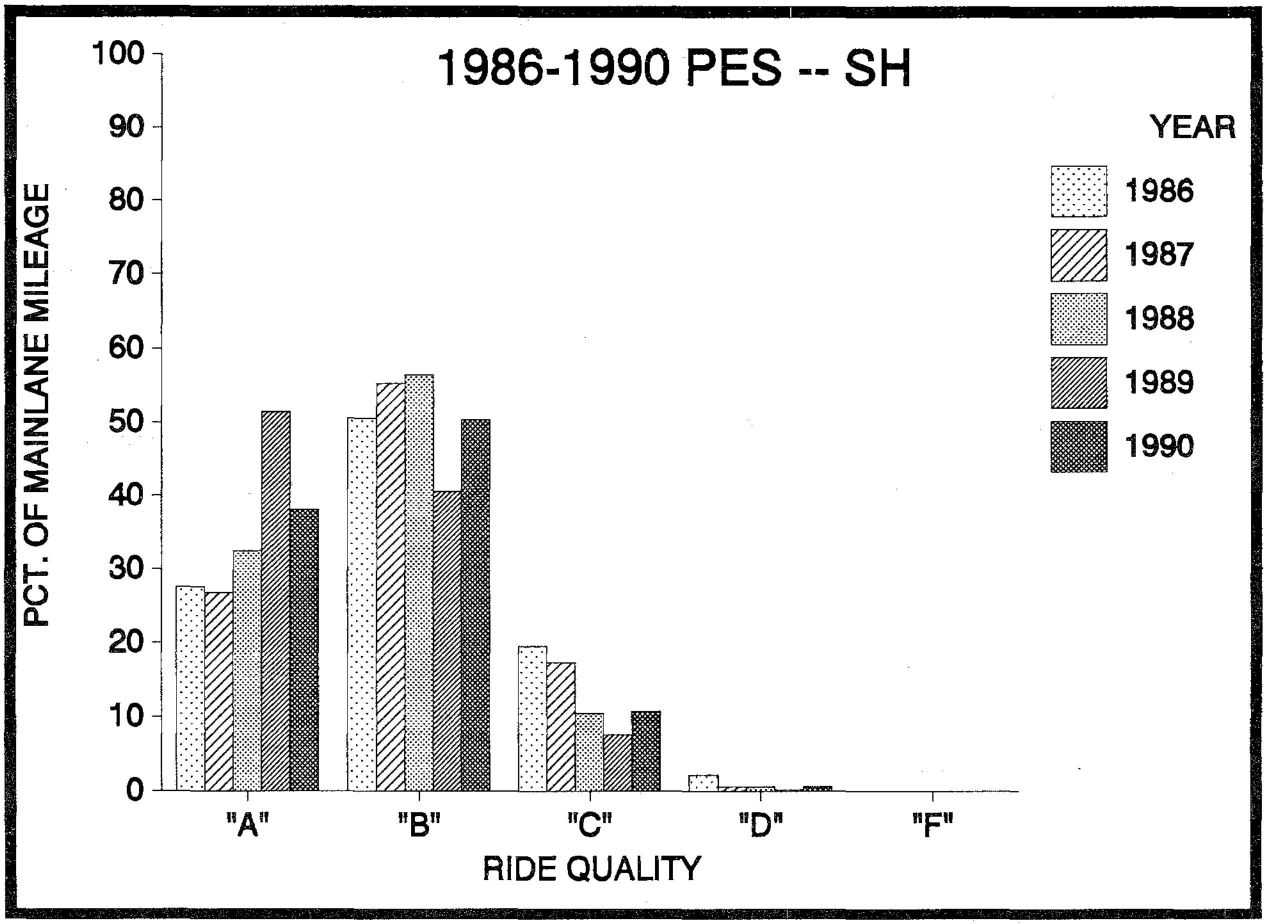


Figure 4.14 -- Ride Quality of SH System 1986-1990.

Ride Quality of the FM System

In 1990, the FM system's ride quality dropped when compared to 1989, but was slightly better than in 1988. 18.5 percent of the rated mainlane mileage had a very smooth ride in 1990, but 23.5 percent had an SI below 3.0. ACP is the predominant pavement type and showed the same trends. The FM system was below the statewide average and had the worst ride quality of the four systems. Figure 4.15 indicates trends in ride quality from 1986-1990.

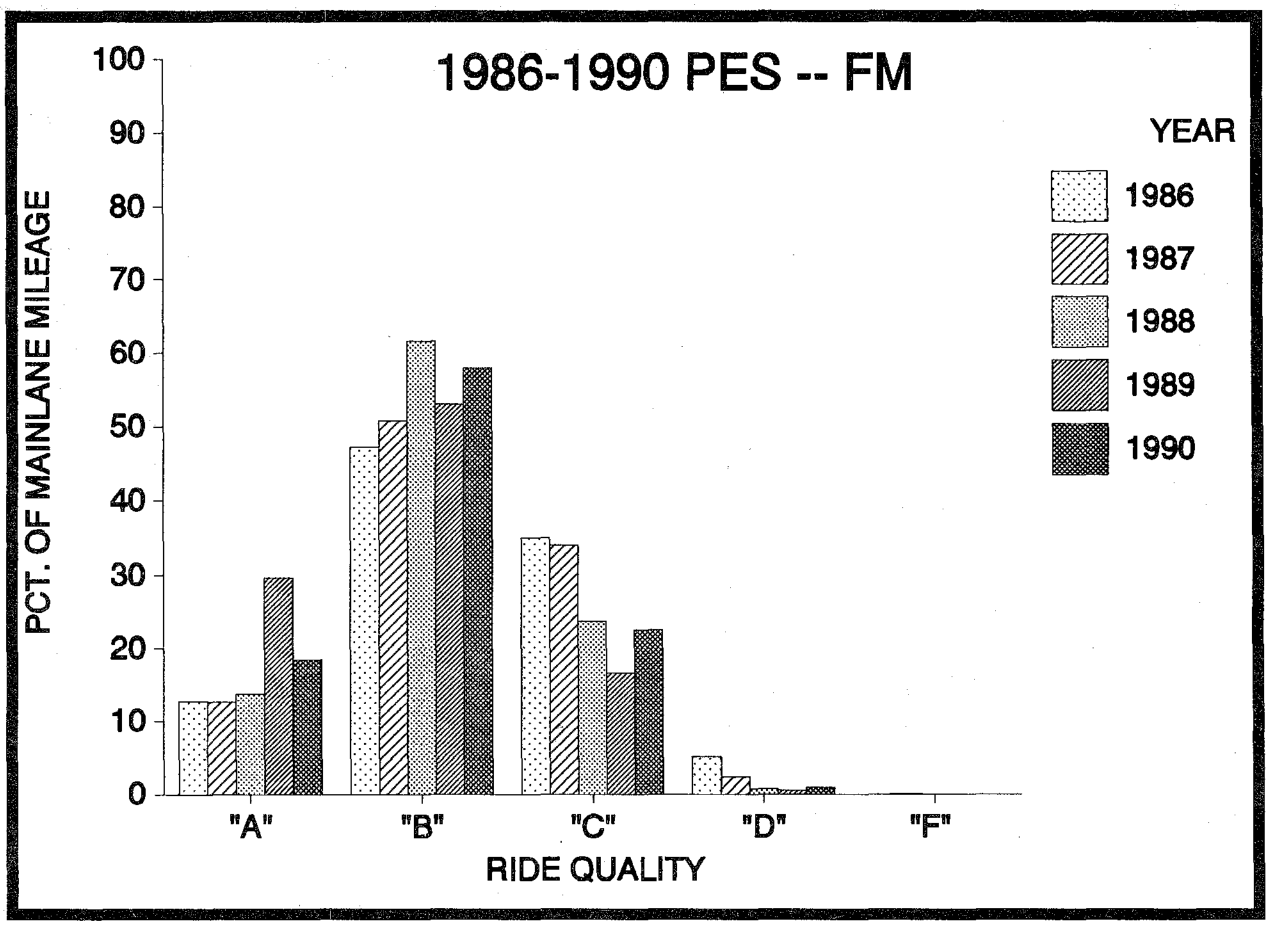


Figure 4.15 -- Ride Quality of FM Network 1986-1990.

ACP Ride Quality

ACP ride quality declined when compared to 1989, with 42.2 percent of the mileage having an SI between 4.0 and 5.0. The amount of mileage having an SI below 3.0 was 10.9 percent, about the same as in 1988. The ride on all highways systems was lower than the 1989 levels, but still better than those of 1988. Figure 4.16 indicates the trend for the last five years.

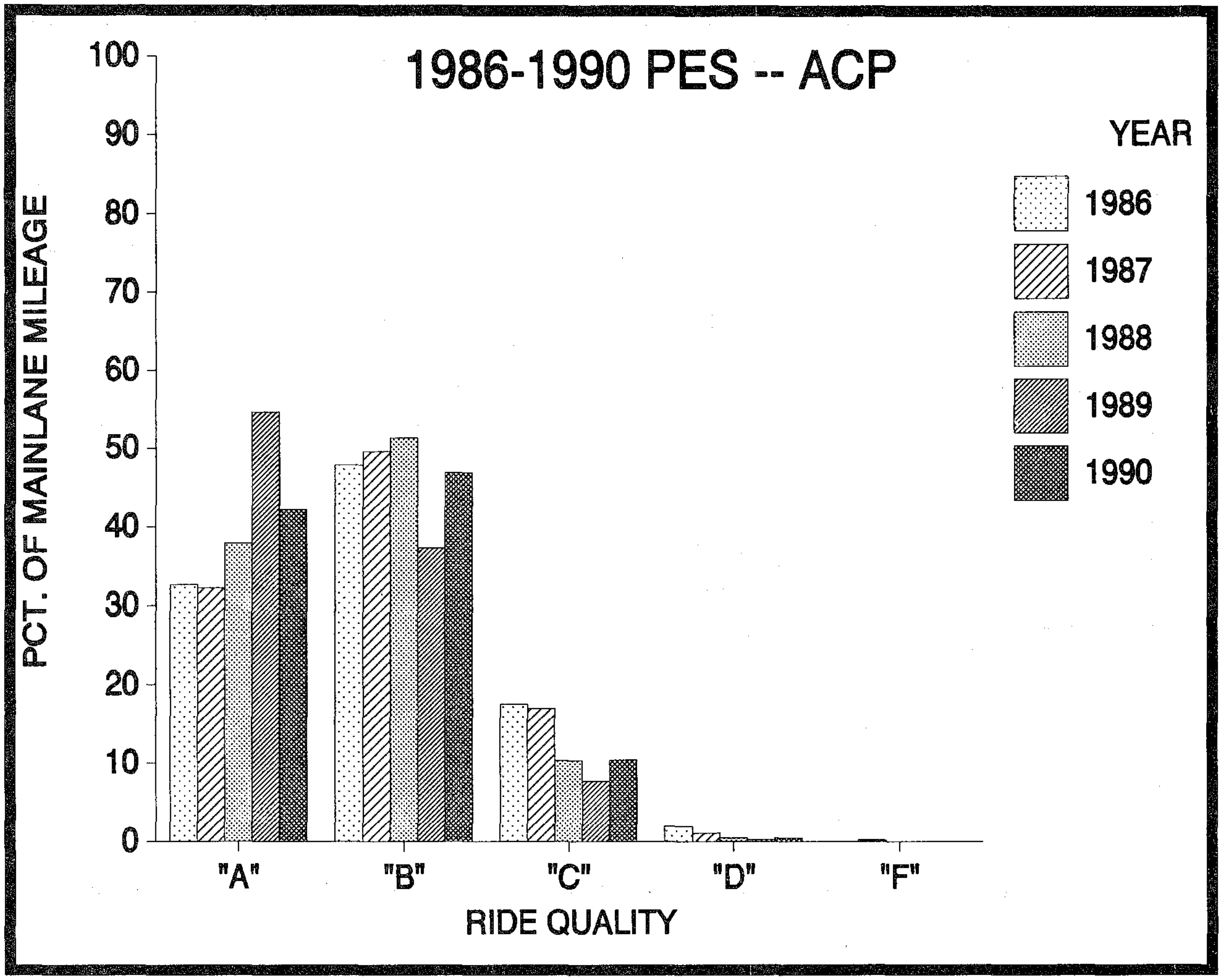


Figure 4.16 -- ACP Ride Quality 1986-1990.

CRC Ride Quality

Ride quality on CRC dropped to its lowest level since 1986, with only 21.1 percent of the system having very smooth ride. The amount of mileage having an SI below 3.0 was 13.2 percent compared to 6.1 percent and 6.2 percent in 1988 and 1989, respectively. The systems with the majority of CRC (IH, US, and SH) all showed the same trends as the statewide CRC. Figure 4.17 indicates the ride quality distribution from 1986-1990.

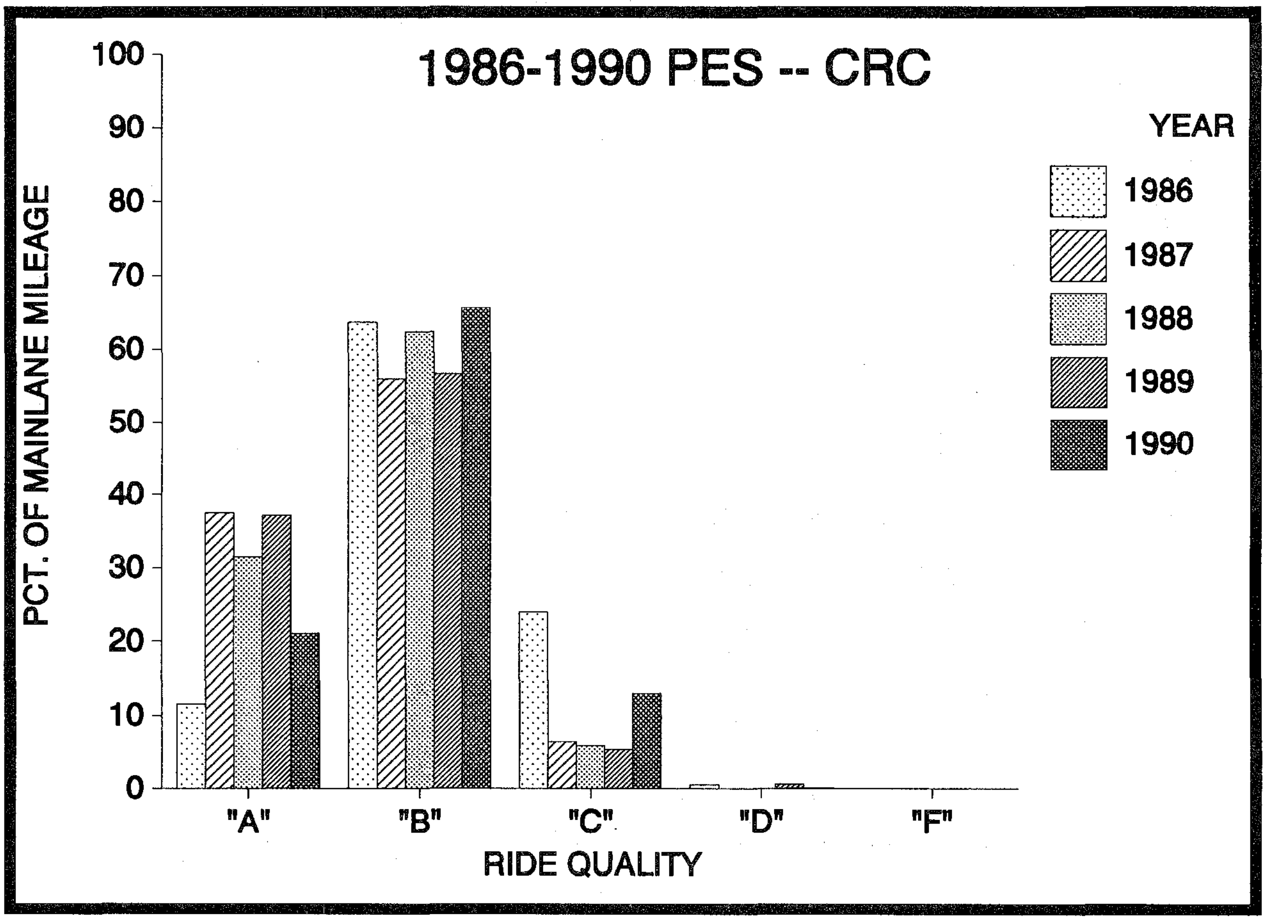


Figure 4.17 -- CRC Ride Quality 1986-1990.

JCP Ride Quality

JCP continued to have the worst ride of the three pavement types in 1990. 46.4 percent of the mileage was below 3.0, the highest since 1986 at 68.1 percent. The small fluctuating sample makes it difficult to place confidence in these trends, except to say that JCP in general is a rough riding surface. JCP on the IH system improved slightly when compared to 1989 while the US and SH systems worsened. Figure 4.18 shows the trends indicated by the 1986-1990 PES ride surveys.

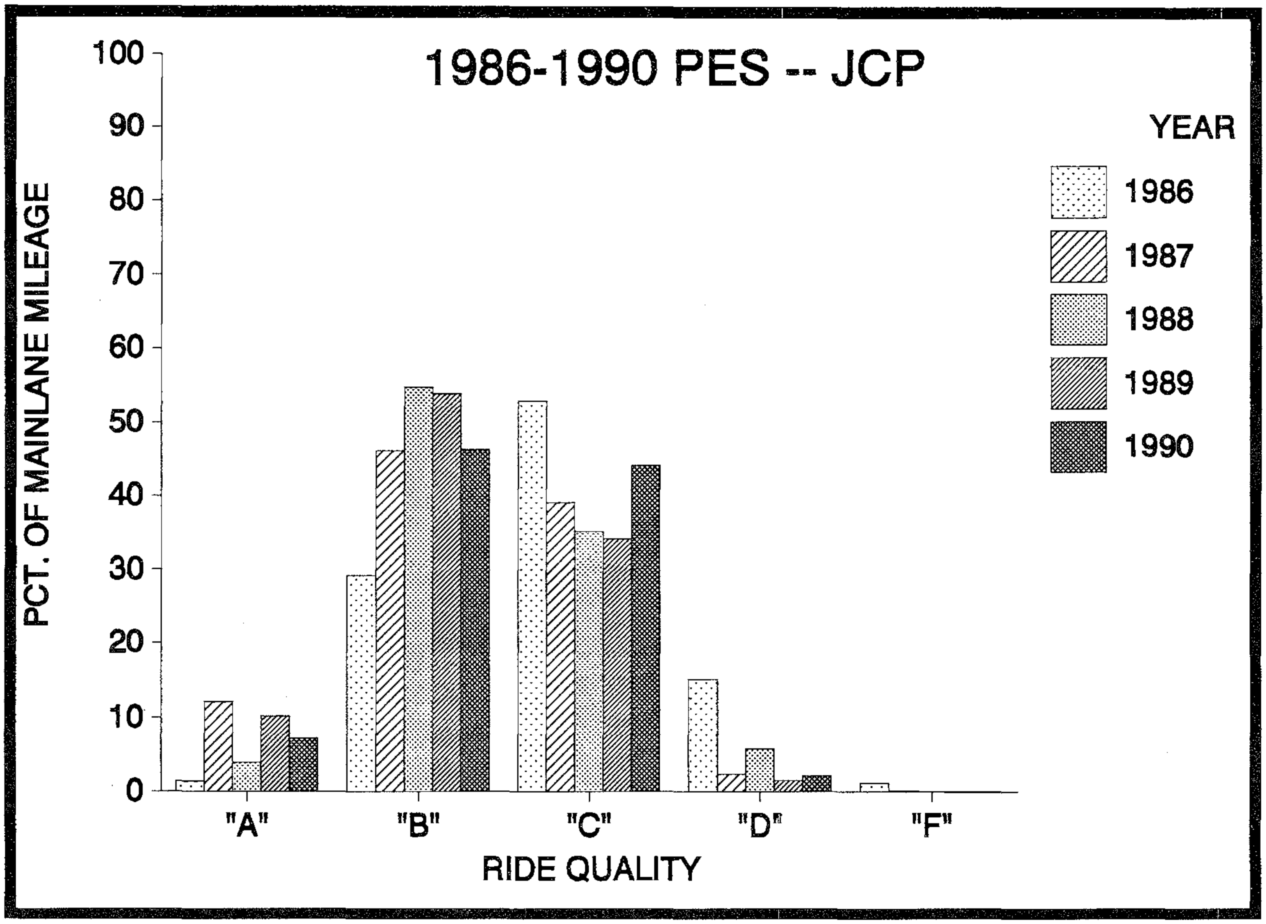


Figure 4.18 -- JCP Ride Quality 1986-1990.

-Notes-

PAVEMENT DISTRESS ON THE STATEWIDE NETWORK

Pavement distress is a measure of visible surface deterioration. PES uses a score called the unadjusted visual utility (UVU) to represent distress. UVU is referred to as Distress score in this section.

In 1990, 67.8 percent of the statewide system had little or no distress. This was a slight decline from 1989 when 69 percent of the system was in class "A". Mileage in the poor and very poor classes remained about the same for the second year in a row at 12.4 percent. The US system was the only system to have a measurable increase in distress. ACP and CRC remained in about the same state while JCP had a increase in distress. Table 4.3 lists the five classes used to describe pavement distress. Figure 4.19 indicates the trends of pavement distress from 1986-1990.

TABLE 4.3 -- Classes of Distress Score.

UVU	CLASS	DESCRIPTION
90-100	"A"	VERY GOOD -- Little or no distress
80-89	"B"	GOOD -- One or two slight distresses
70-79	"C"	FAIR -- Multiple distress types, or one severe distress
60-69	"D"	POOR -- Multiple distress types with at least one severe distress
1-59	"F"	VERY POOR -- Combination of moderate and severe distresses

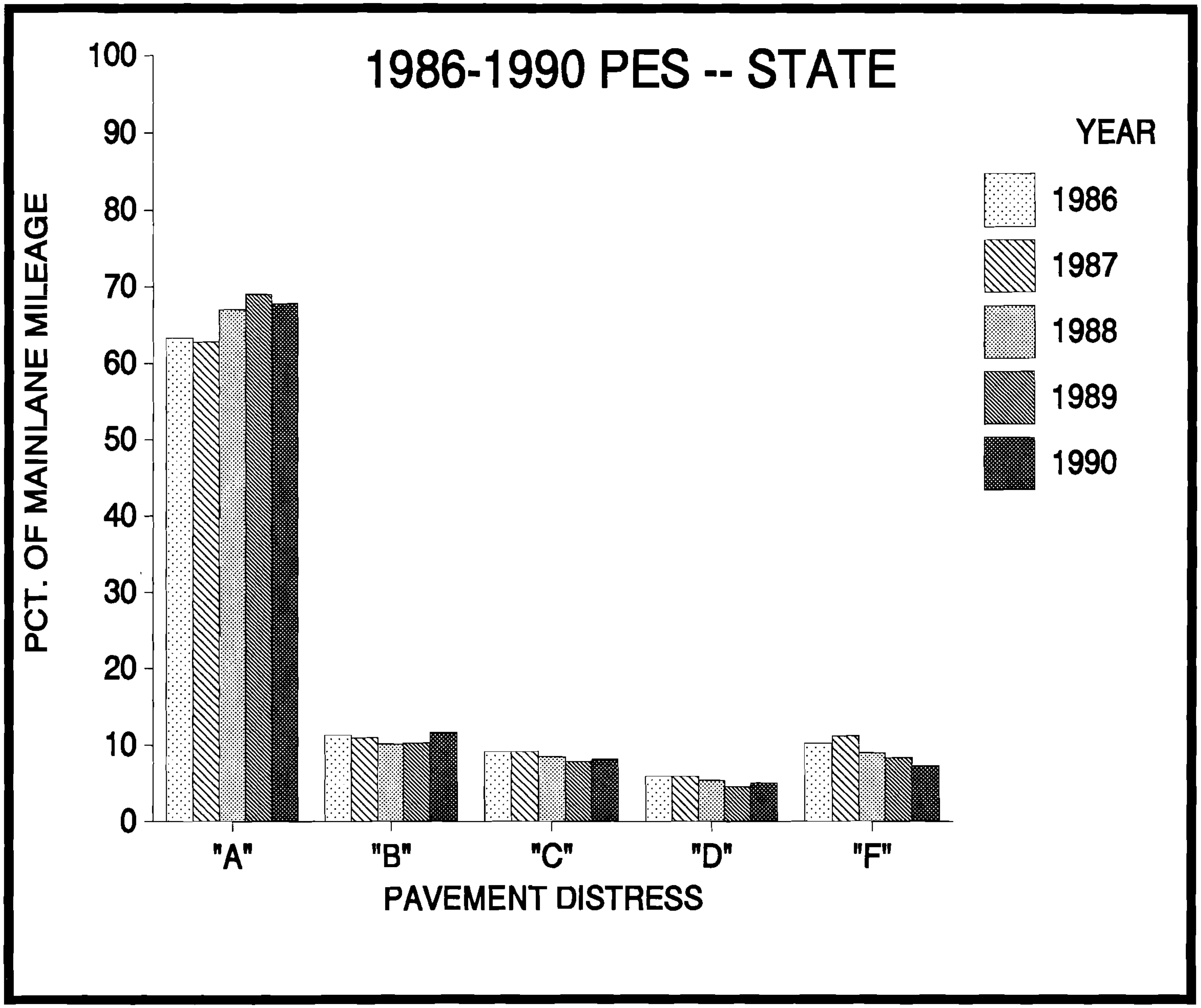


Figure 4.19 -- Pavement Distress of the Texas Highway Network 1986-1990.

Pavement Distress on the IH System

The 1990 PES survey indicated that 79.1 percent of IH mileage had a very good distress score while 8.4 percent was in the poor to very poor classes. This showed a slight improvement over the 1989 survey. CRC had an increase in class "A" mileage, while ACP remained about the same. JCP decreased in very good mileage and had a large increase in class "F". Figure 4.20 indicates the distress score distribution from 1986-1990.

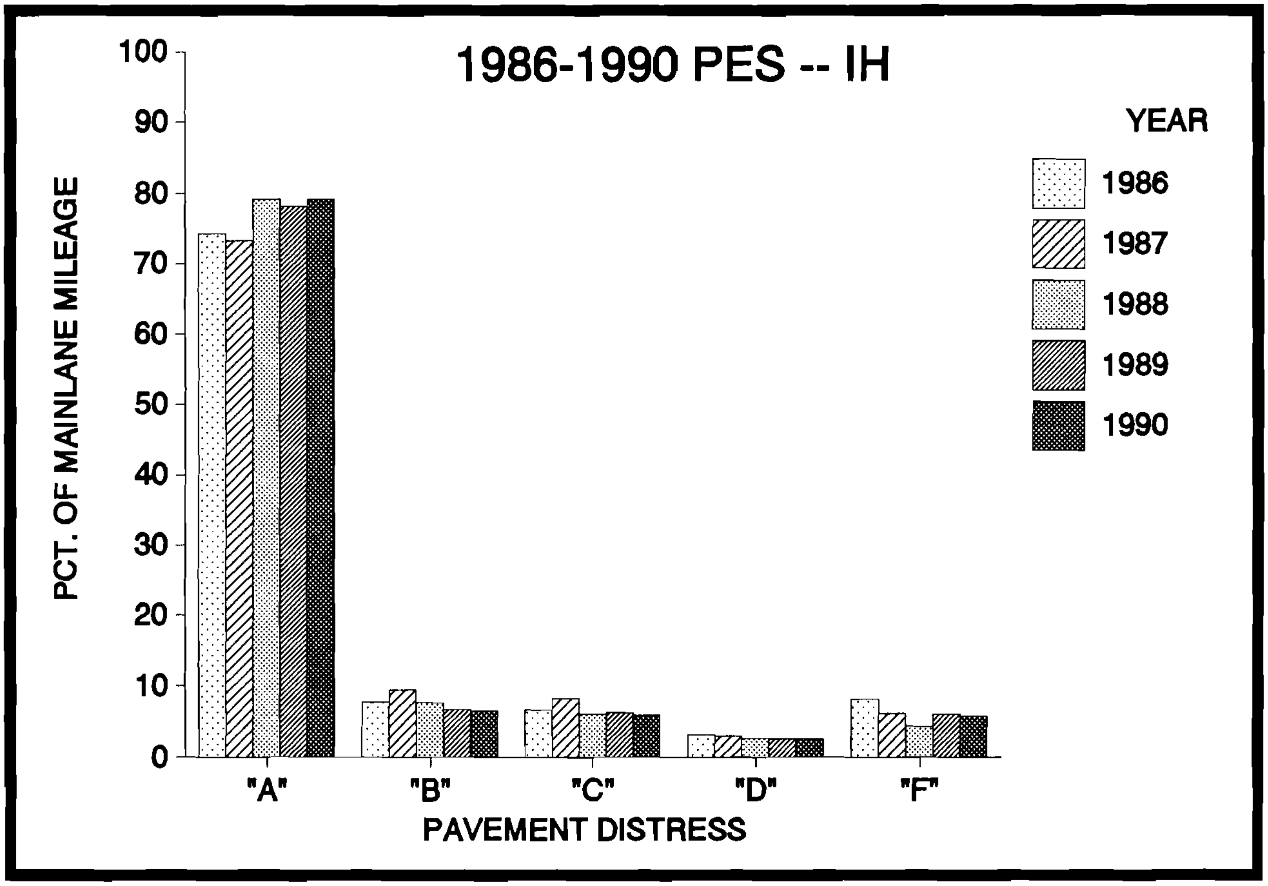


Figure 4.20 -- Pavement Distress of the IH Network 1986-1990.

Pavement Distress on the US System

The US system had slightly more distress in 1990, with 67.7 percent in class "A", as compared to 70.3 percent in 1989. Thirteen percent of the mileage was in classes "D" and "F", the second lowest amount in five years. All three pavement types had a decrease in very good mileage. CRC and JCP had an increase in poor to very poor mileage, with CRC at 21.4 percent, its worst state since 1986. Figure 4.21 indicates the trends in distress from 1986-1990.

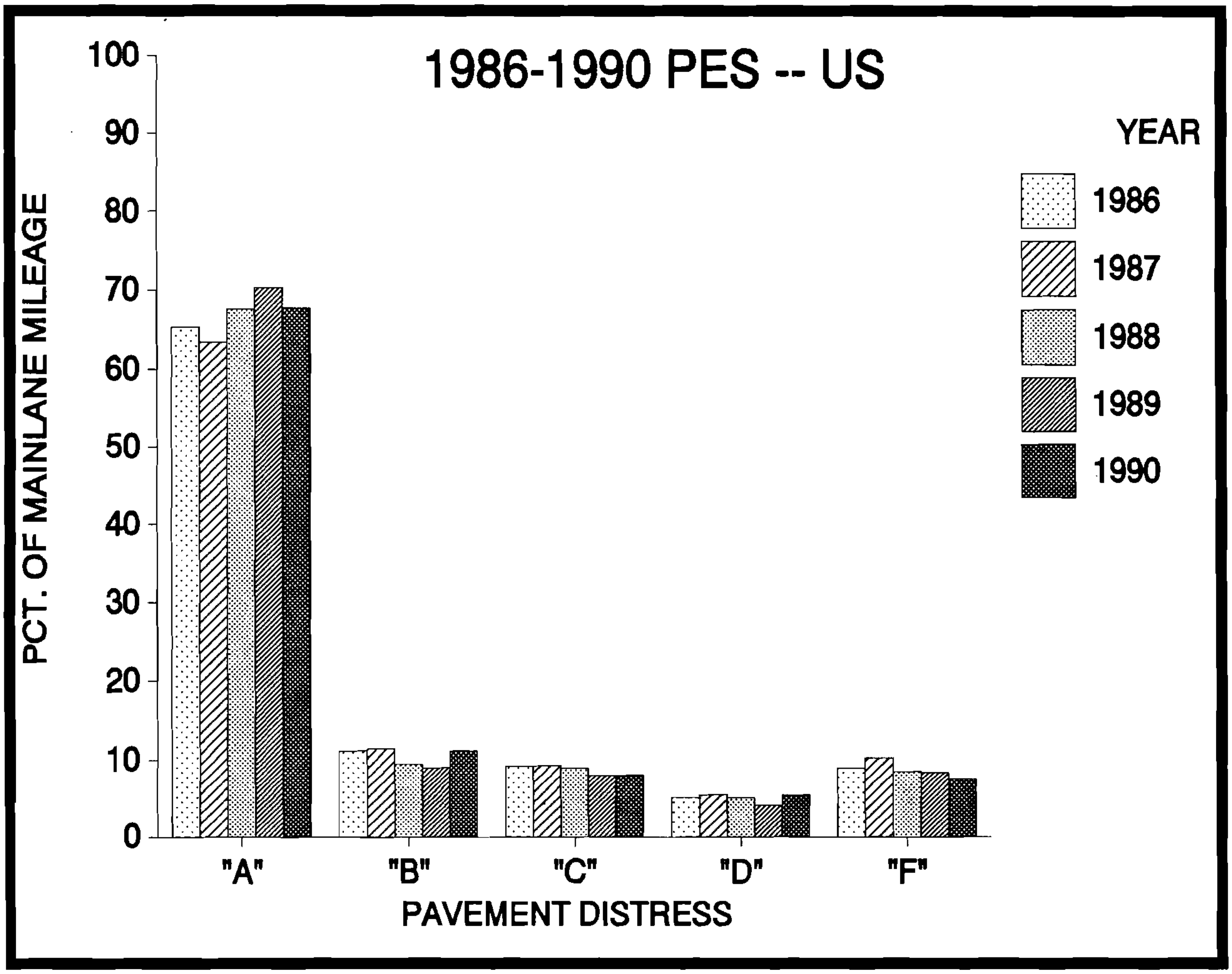


Figure 4.21 -- Pavement Distress of the US Network 1983-1989.

Pavement Distress on the SH System

In 1990, the SH system had 68.1 percent of its mileage in very good class. This was down from 1989 (69.2 percent), but was the second best percentage in the last five years. The percentage of mileage with a poor to very poor distress score was 10.8 percent, down slightly from 1989 and the lowest percentage in five years. Of the three pavement types only ACP remained about the same, while CRC and JCP had more distress. Figure 4.22 indicates the distress score distribution from 1986-1990.

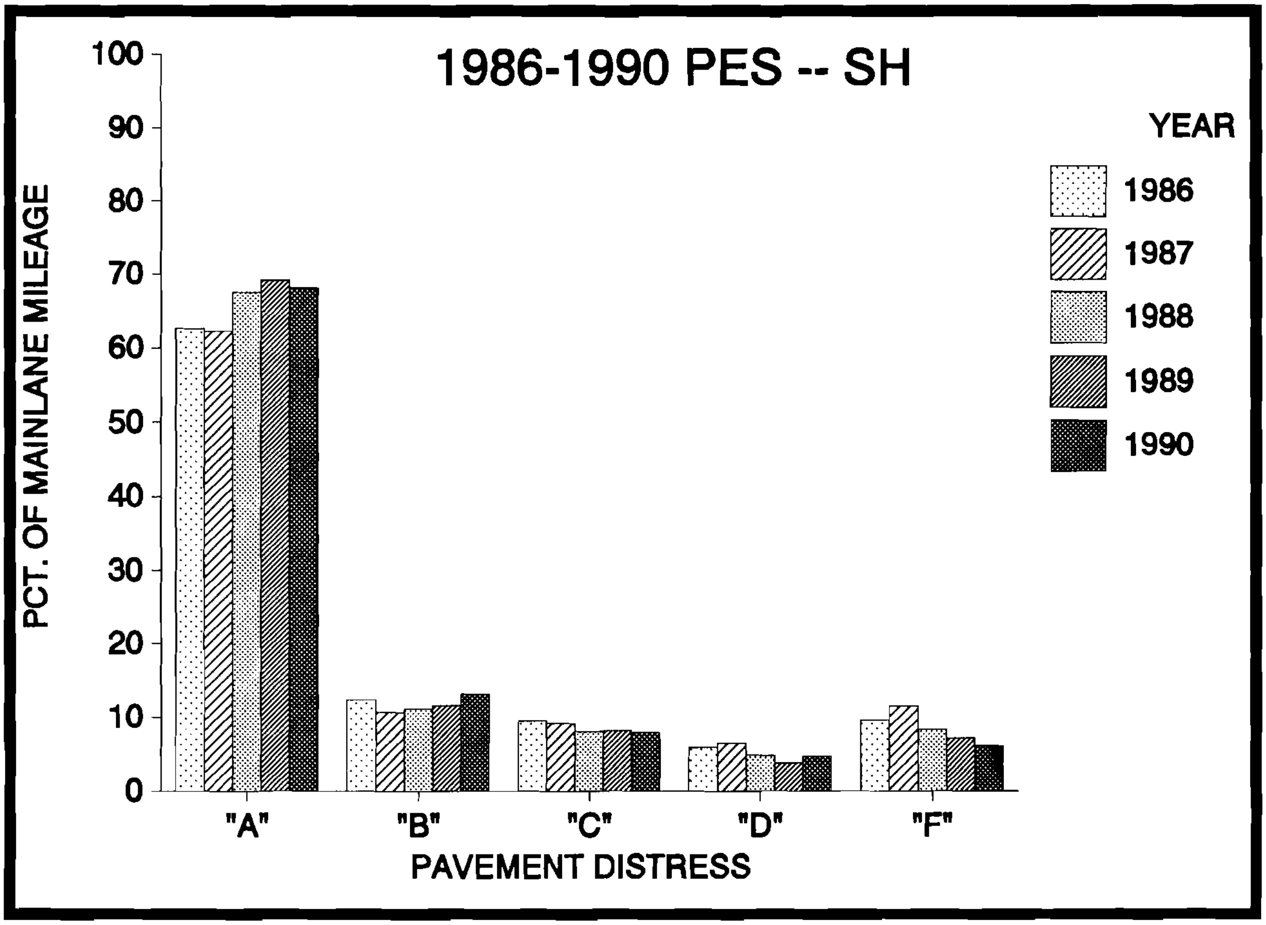


Figure 4.22 -- Pavement Distress of the SH Network 1986-1990.

Pavement Distress on the FM System

In 1990, the FM system had about the same mileage in the very good class at 60.0 percent, compared to 60.4 percent in 1989. The percentage of mileage with a poor to very poor distress score was at 16.1 percent, the lowest level since PES began in 1983. However, the FM system still had the most distress of all highway systems. Figure 4.23 indicates the distress score distribution from 1986-1990.

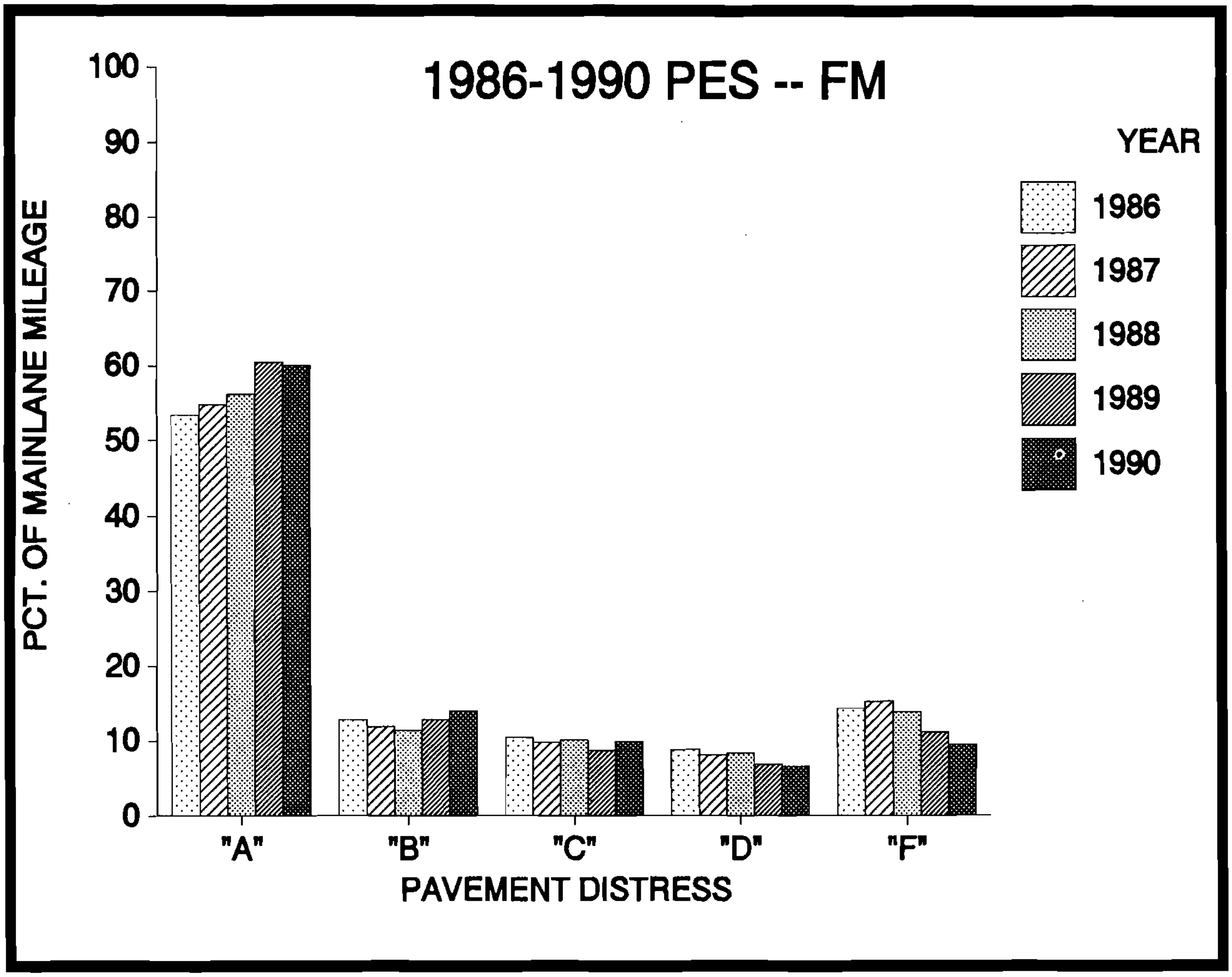


Figure 4.23 -- Pavement Distress of the FM System 1986-1990.

ACP Pavement Distress Score

In 1990, the amount of distress on ACP remained about the same as in 1989. Class "A" mileage was down slightly at 67.1 percent compared to 68.1 percent in 1989. However poor and very poor mileage was at its lowest level since PES began, at 12.2 percent. Looking at the four highway systems, the FM system improved slightly, while the Interstate and State Highways remained about the same, and the US system worsened slightly. The statewide trends for the last five years are illustrated in Figure 4.24.

Individual ACP distresses will now be examined.

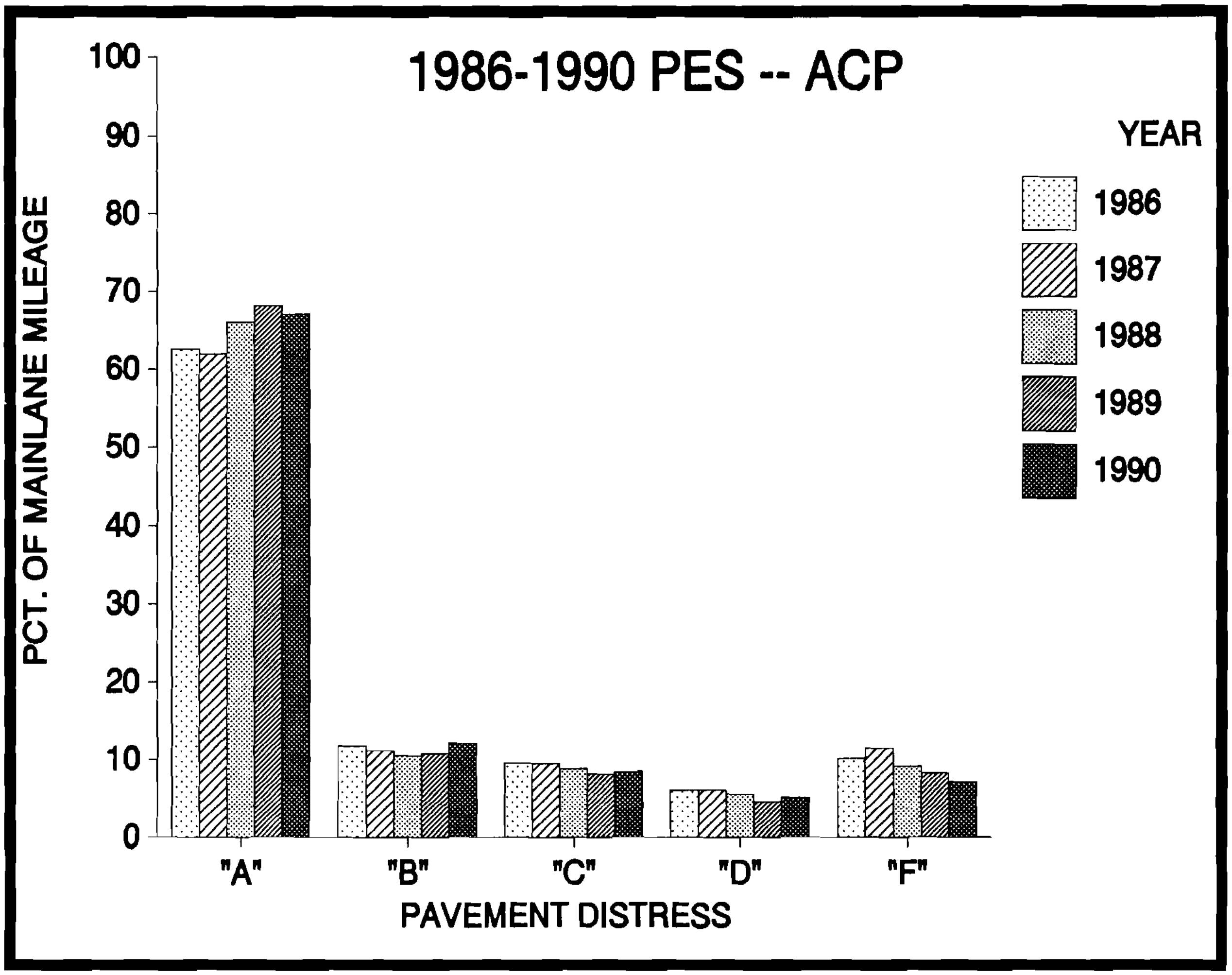


Figure 4.24 -- ACP Pavement Distress 1986-1990.

Rutting

Rutting was down slightly in 1990. It was observed on 30.1 percent of the rated ACP sections. This was only 0.6 percent lower than in 1989. For the last five years rutting has been seen on approximately 30 percent of the sections, with 1987 having the highest level at 33.5 percent. Even though rutting has decreased from 1989, it was the second highest among all ACP distresses. In 1990, the FM system was the only system with increase rutting, and was still the system with the most rutting. The IH system continued to have the least rutting at 17.9 percent. Figure 4.25 shows the percentage of rutting by highway system from 1986-1990. The minimum amount of rutting needed in a typical two-mile section is 211 feet of ½"-3" deep rutting. If the rut is less than ½" deep it is not rated.

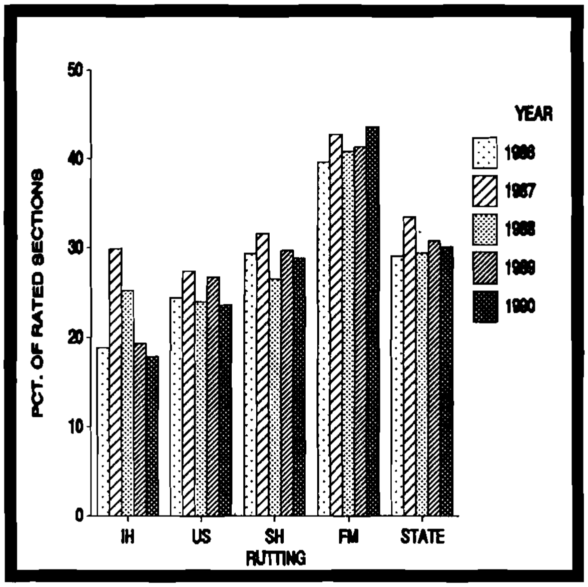


Figure 4.25 -- Rutting, by System, 1986-1990.

Patching

The frequency of patching was down in 1990 and has decreased each year for the last five years. In 1990, only 22.1 percent of the rated ACP sections had a measurable amount of patching. The FM system continued to have the most patching, while the Interstate still had the least. Figures 4.26 shows the amount of patching by highway system from 1986-1990.

In 1990, the percentage of sections with cracking distresses increased. This usually results in an increase occurrence of patching. The reason for the decrease in patching is unknown. However, it may be due to an expanded use of full roadway width patches that are over 500'. This is considered an overlay by PES and is not rated. The minimum rating amount of full lane width patching in a typical two-mile section is 106 feet.

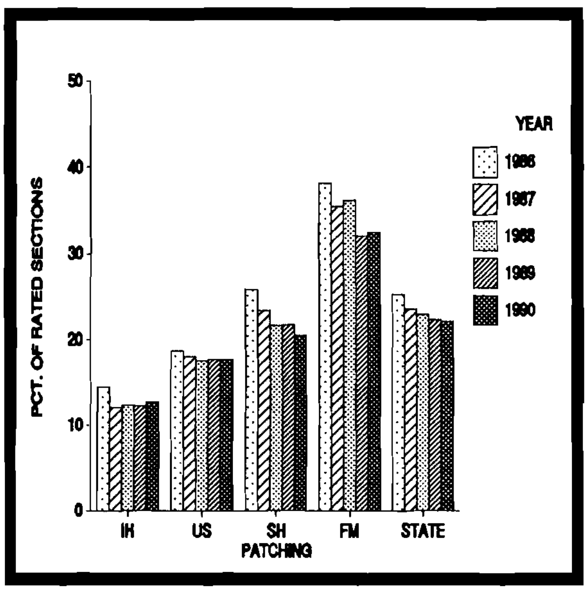


Figure 4.26 -- Patching, by System, 1983-1989.

Failures

In 1990, the frequency of failures increased. Failures occurred second lowest among the ACP distresses at 4.2 percent. The FM system again had the most sections with failures, while the IH system had the least. Figure 4.27 shows the percentage of rated sections with failures by highway system from 1986-1990. The minimum number of failures reported in a typical two-mile section is two.

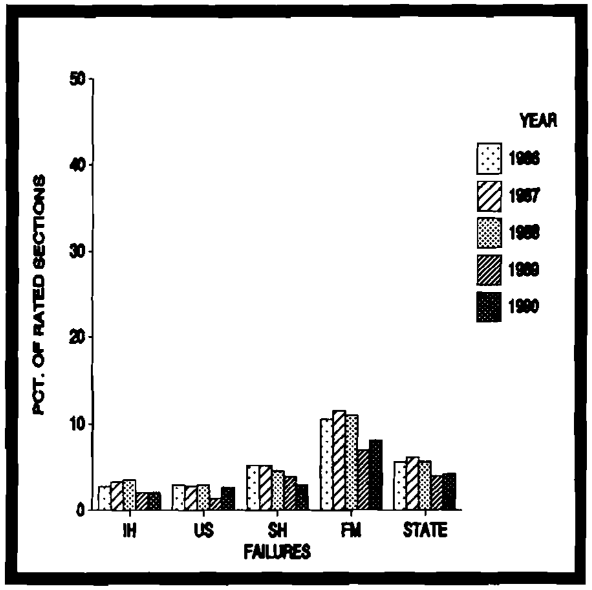


Figure 4.27 -- Failures, by System, 1986-1990.

Block Cracking

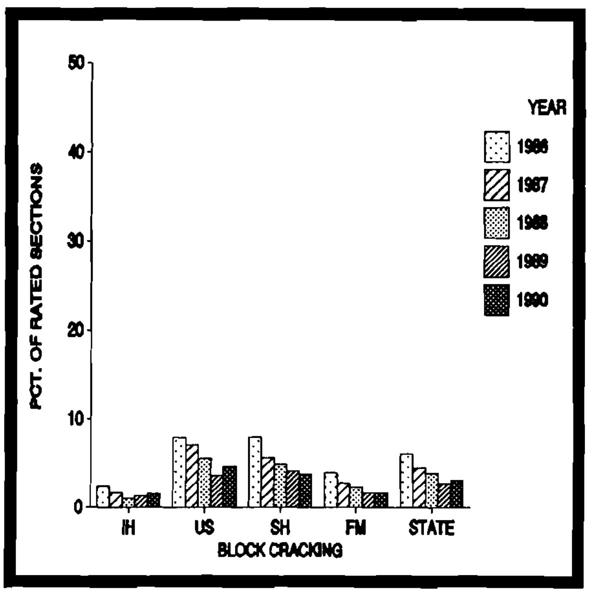


Figure 4.28 -- Block Cracking, by System, 1986-1990.

The frequency of block cracking rose slightly in 1990 to 3.1 percent. The distress was still at one of its lowest levels in the last five years. Block cracking was the least frequently observed ACP distress type. The highway system with the highest percentage of block cracking was the US followed by the SH system. The FM and IH systems had the same amount of block cracking (1.6 percent). Figure 4.28 shows the percentage of rated sections with block cracking by highway system from 1986-1990. The minimum amount of full lane width block cracking reported in a typical two-mile section is 106 feet.

Alligator Cracking

In 1990, the PES survey showed an increase in alligator cracking. This was the first increase for alligator cracking since PES begin in 1983. However, the frequency of the distress remain lower than years before 1989. The FM and US systems had the most alligator cracking at 11.2 percent and 11.1 percent respectively. The Interstate had the least at 5 percent.

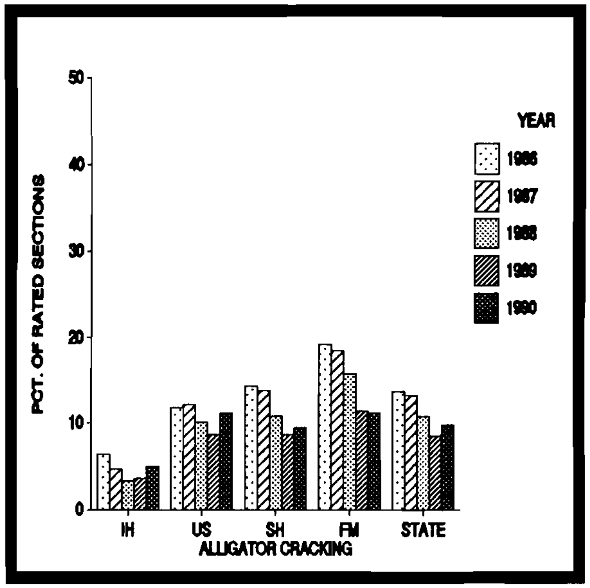


Figure 4.29 -- Alligator Cracking, by System, 1986-1990.

Alligator cracking is a load and material related distress. Typically the FM, SH, and US systems are built to lower structural standards than the IH system and consequently are more susceptible to the load-related distresses. Figure 4.29 shows the percentage of rated sections with alligator cracking from 1986-1990. The minimum amount of alligator cracking reported in a typical two-mile section is 211 feet.

Longitudinal Cracking

Longitudinal cracking increased in 1990 to its 1987 level of 30.9 percent. Longitudinal cracking had the highest occurrence among all ACP distress in 1990. The IH system had the most sections with longitudinal cracking at 38.6 percent, while the FM system had the least at 24.0 percent.

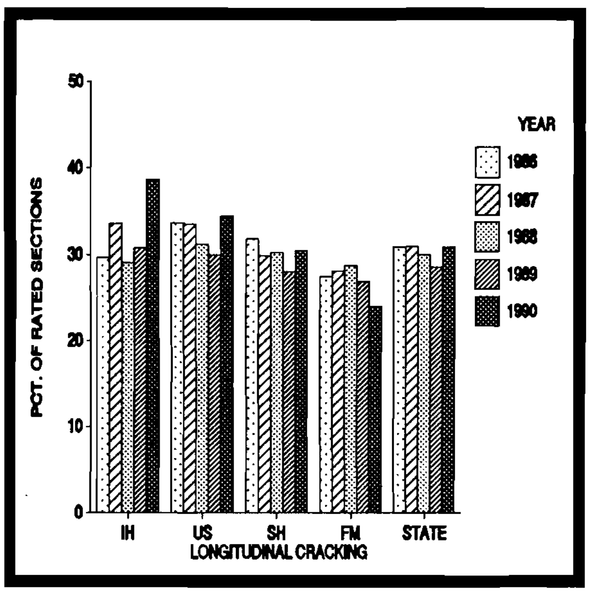


Figure 4.30 -- Longitudinal Cracking, by System, 1986-1990.

Longitudinal cracking is a load and weather related distress. Stiffer pavements develop longitudinal cracking first in the wheelpaths instead of alligator cracking. If left untreated these longitudinal cracks will eventually lead into alligator cracking. These stiffer pavements also develop more cracking due to thermal changes. Figure 4.30 shows the percentage of rated sections with longitudinal cracking from 1986-1990. The minimum amount of longitudinal cracking reported in a typical two-mile section is 1056 feet.

Transverse Cracking

Transverse cracking increased in 1990, with 25.3 percent of rated sections having the distress. The 1990 survey indicated the highest percentage since 1987, when it was rated on 25.9 percent of the sections. The US system had the highest percentage of transverse cracking with 36.3 percent, while the FM system had the least at 11.8 percent.

Transverse cracking is a weather and material related distress. Because of the stiffer pavements, transverse cracking is seen more on the IH, US, and SH systems. Also these three systems have overlaid JCP, which results in reflective cracking. Figure 4.31 shows the percentage of reported mainlane sections with transverse cracking from 1986-1990. The minimum number of full lane width transverse needed in a typical two-mile section is 106.

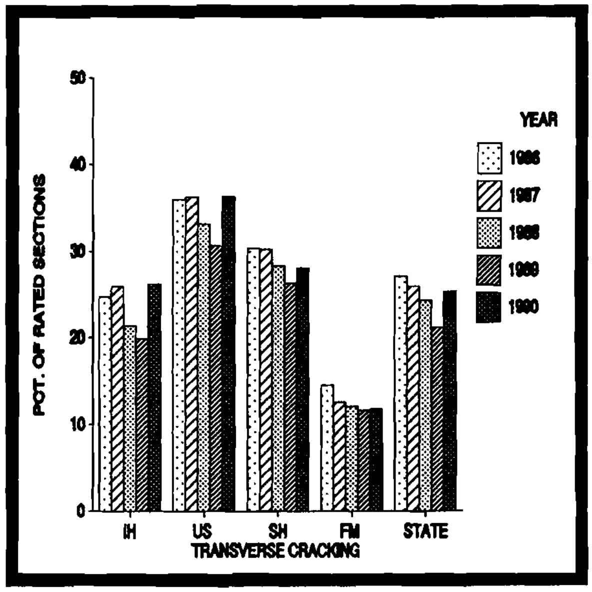


Figure 4.31 -- Transverse Cracking, by System, 1986-1990.

CRC Pavement Distress Score

CRC had slightly less pavement distress in 1990 compared to 1989. The amount of class "A" mileage in 1990 was 80.1 percent with classes "D" and "F" at 12.5 percent. In 1989, class "A" mileage was at 79.4 percent with classes "D" and "F" at 13.0 percent. In the last five years. In 1990, the US and SH CRC had more distress, than the Interstate. The reason for the improvement in 1990 could be attributed to newly constructed pavements entering the survey, the fluctuating sample, or the variance in the PES distress ratings. Figure 4.32 shows the distress score distribution from 1986-1990.

Figures 4.33 through 4.36 indicate the distribution for each distress. Notice that the overall percentage of sections with distresses (Figure 4.33-4.36) did not increase much in 1990 indicating that the amount of distress on individual sections increased(e.g., number of spalled cracks increasing from 10 to 20). The FM system is not shown, since CRC is rarely used. Also, notice that the SH system had a decrease in percentage of punchouts, concrete patches, and asphalt patches. This indicates that CRC pavement is being removed or overlaid.

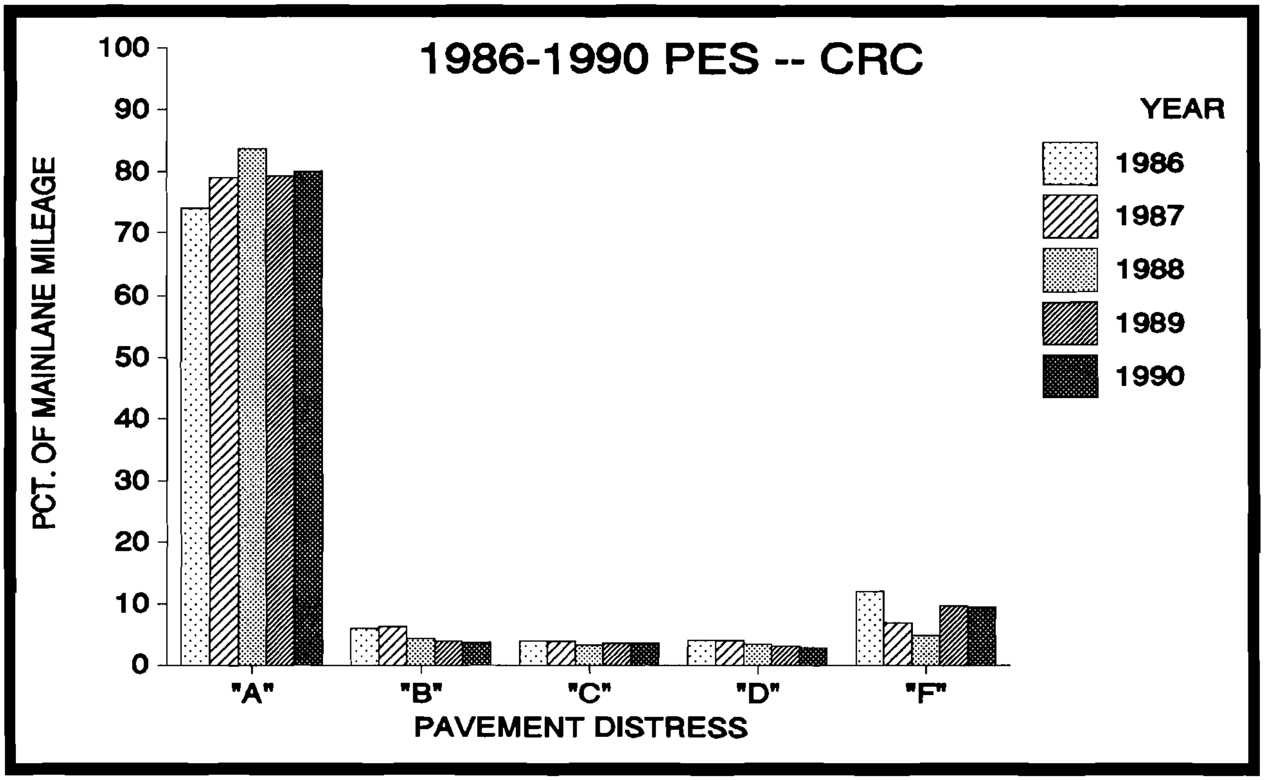


Figure 4.32 -- CRC Pavement Distress 1984-1989.

Spalled Transverse Cracks

In 1990, the frequency of spalled transverse cracks dropped to 54.7 percent, the lowest level since 1987. Each highway system showed this decreasing trend. The US system had the highest percentage at 60.5 percent in 1990, yet was the lowest level in the last five years. Spalled transverse cracks occurred the most often of all CRC distresses. This is reasonable because CRC pavements tend to crack (spall) first, then develop more severe distresses. Figure 4.33 shows, by system, the percentage of sections with at least one spalled transverse crack, from 1986-1990.

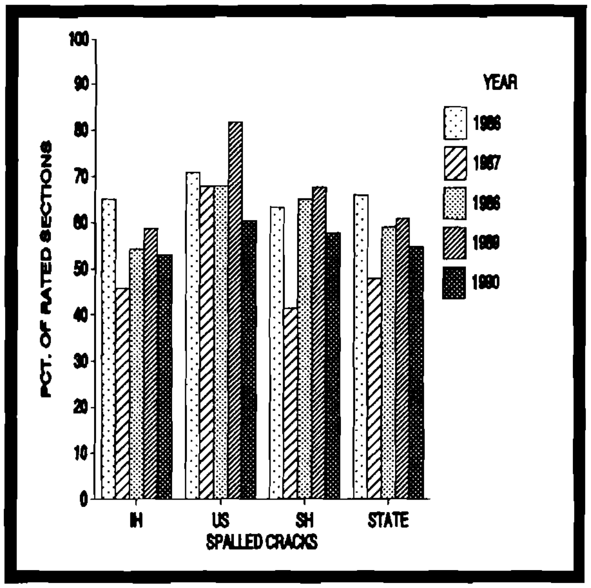


Figure 4.33 -- Spalled Cracks, by System, 1984-1989.

Punchouts

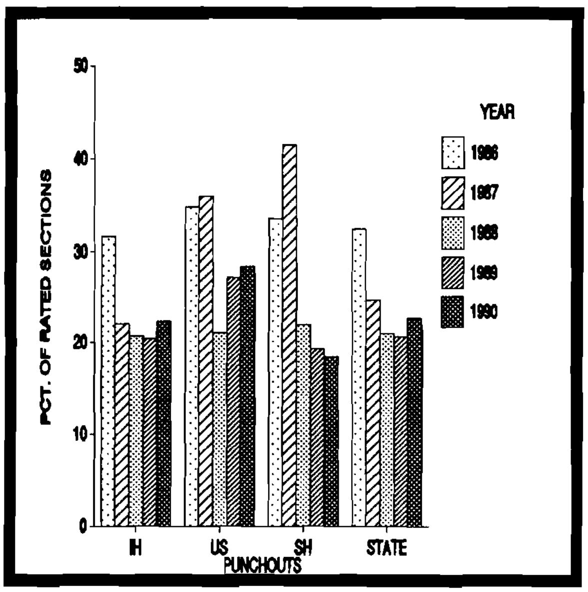


Figure 4.34 -- Punchouts, by System, 1986-1990.

In 1990, the frequency of punchouts increased. Punchout sections were at 22.7 percent, compared to 21.0 and 20.7 percent in 1988 and 1989. This is the highest level since 1987, when 24.7 percent of the sections had punchouts. The frequency of punchouts increased on the US and IH systems while it decreased on SH system. The highway system with the highest frequency was the US at 28.5 percent. The overall increase may indicate a lack of maintenance funds or low priority in correcting this distress. Figure 4.34 indicates, by system from 1986-1990, the percentage of sections with at least one punchout, by highway system.

Asphalt Patches

The frequency of asphalt patches increased to 13.6 percent in 1990. The percentage in 1989 was 10.8. The increase in sections with asphalt patches may be attributed to a larger, 1990 sample. However, it could be caused by a decrease in maintenance funds. 1990 had the second lowest frequency of asphalt patches in the last five years. The IH and US systems showed increases in sections with the distress, while the SH system indicated a decrease. Figure 4.35 shows the percentage of sections with at least one asphalt patch, by highway system, from 1986-1990.

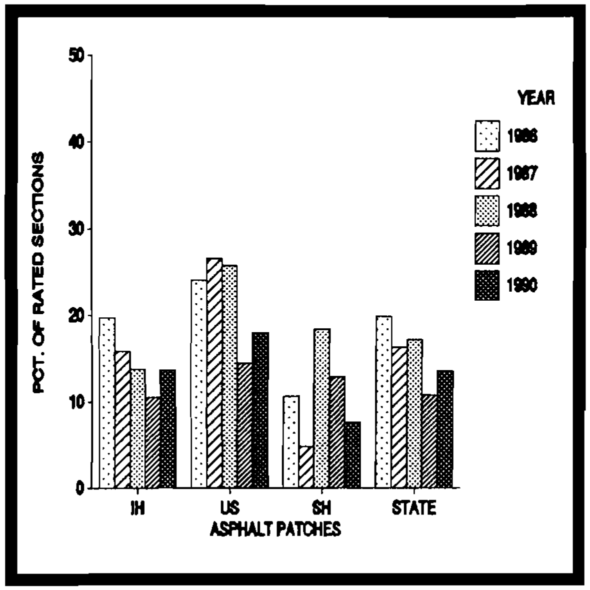


Figure 4.35 -- Asphalt Patches, by System, 1986-1990.

Concrete Patches

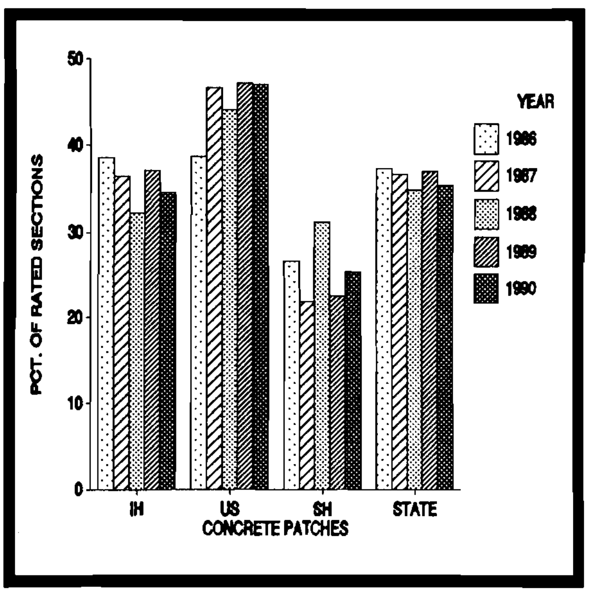


Figure 4.36 -- Concrete Patches, by System, 1986-1990.

The frequency of concrete patching was down in 1990 at 35.2 percent and was the second lowest since 1988. The decrease of sections with concrete patching could be due the patch failing and rated as a punchout. Also the patch may have failed and was replaced with an asphalt patch or the entire pavement section may have been reconstructed or overlaid. The Interstate showed a decrease, while the SH system showed an increase with US highways remaining stable. Figure 4.36 shows the percentage of sections with at least one concrete patch, by highway system, from 1986-1990.

JCP Distress

The 1990 PES survey data indicated that JCP distresses increased when compared to 1989. Because 1990's sample size was larger than 1989, very little confidence can be placed in this finding. The only conclusion which can be reached with confidence is that JCP has the highest distress frequency of the three pavement types. The effects of sample size can be seen in the figure below. The even years, having the larger samples, always indicate more distress than the preceding odd years. Figure 4.37 shows the pavement distress trends from 1986-1990.

Because of the fluctuating sample size, individual JCP distresses were not analyzed. The problem of representative data for the JCP should be resolved with the implementation of a 100-percent survey starting in September, 1991.

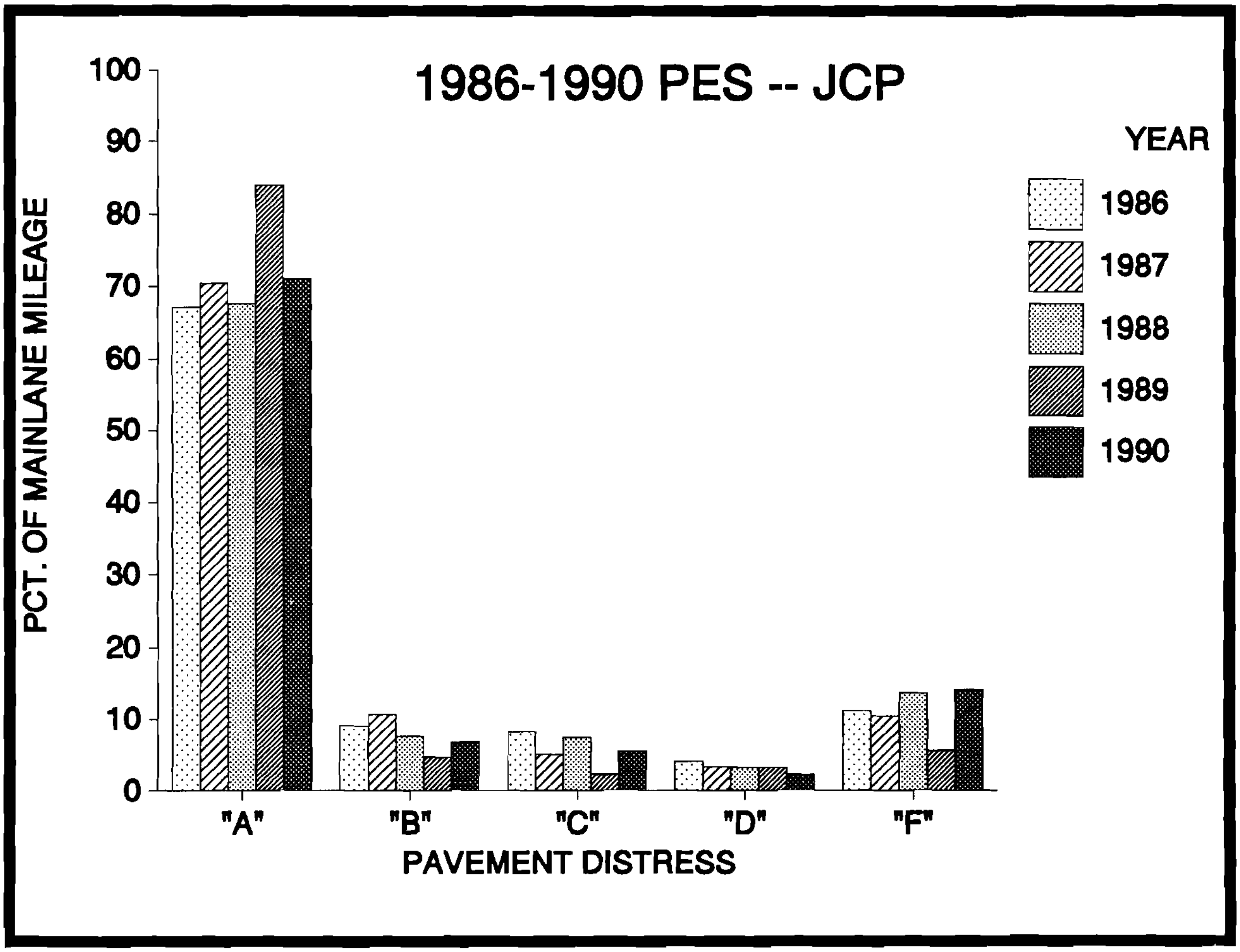


Figure 4.37 -- JCP Pavement Distress 1986-1990.

Summary of Overall Network Condition

The overall pavement condition of the Texas highway network improved from 1986-1989. In 1990, the network condition declined slightly. This decline was evident on all highway systems and the three pavement types. This decrease was influenced by both ride quality and pavement distress.

The 1990 ride quality survey had a large percentage of very smooth mileage drop into the smooth category, when compared to the 1989 data. The shift was caused by the inaccurate 1989 survey as discussed in Chapter 3. This problem was resolved in 1990, and as expected the overall ride quality dropped to approximately 1988 levels. Ride quality, by pavement type, indicated that only ACP remained around the 1988 level. CRC and JCP dropped below the 1987 level. The IH system showed the most lost in service.

Overall pavement distress increased above 1989 levels, but remained below 1988 levels. The increase in distress was due to worsening condition on the US and SH systems, while the IH and FM systems indicated improved condition. Distress by pavement type indicated that CRC was the only type to have less distress in 1990. The survey showed a large rise in JCP distress, however the small fluctuating sample provides little confidence in the finding. ACP deteriorated only slightly compare to 1989 data, with rutting, patching, and failures remaining stable, while the other distresses showed increases. Even though rutting did not increase, it is still present on 30 percent of rated sections.

The decline in overall condition in 1990 was the first decrease in pavement condition since 1984. This decline in condition may be the combined results of the 1989 incorrect ride survey and deviations in the distress survey. Another contributor to the decrease in overall condition may be the cold, wet weather of December, 1989 and February, 1990, which was first measured in the 1990 PES survey. This is reinforced by the increased cracking distresses, the first in the last five years. Construction and maintenance funding reductions may also have augmented the decline as will be shown in Chapter 9. All of this combined with the effects of more cold wet weather in December 1990, (which is just now being measured) suggests that the condition of Texas pavements peaked in 1989. Future survey will show if this condition downturn is the effect of random error or the beginning of a trend.

CHAPTER 5
ESTIMATED FUTURE CONDITION OF TEXAS PAVEMENTS

The future condition of Texas highways is predicted based on previous years PES data, as shown in Chapter 4. The following predictions are performed only for asphalt pavements. The same concepts can be applied to rigid pavements, individual pavement types, or subgroups of asphalt or rigid pavements.

Prediction tables of distress ratings and score classes were obtained for asphalt pavements from the PES historical data. Funding levels and inflation are already included in the PES data, thus they will automatically be incorporated into the prediction tables. The next page describes the derivation of the prediction tables in detail.

The remainder of the chapter discusses the prediction tables and five-year projections of current condition, ride quality, and pavement distress score categories for asphalt pavements. The pavement distress section is further subdivided into a discussion for each asphalt distress type with individual prediction tables and five-year projections.

The percentage values in these prediction tables are a starting point for predictions. These values will change as more historical data are collected, and included in the analysis.

Due to the increase in the level of funding for construction and maintenance in the first half of the period spanning from 1983 to 1989 and the decrease in funding in the last half of the same period, the projection values for each prediction table are not representative of expected deterioration under steady state funding. If the level of funding were constant or steady state, the prediction table value for a distress or a score class will have a 50/50 chance of being better or worse than its current value. However, all of the prediction tables have near a 70/30 better/worse ratio , thus indicating an overall improvement. This causes the future projections to reach a level of steady state in a shorter period of time.

Analysis Procedures for Future Conditions

Distress ratings or score categories of PES survey sections for a given year were compared to the same survey sections of the next consecutive year. If data for the next consecutive year did not exist, the distress ratings or score classes were compared to the same survey sections of every third year.

This model of comparison with the seven years of PES historical data produced a statistical count of rate-of-change for each survey section. The rate-of-change was defined as the tendency for the section to worsen, remain unchanged, or improve from year to year. A percentage of rate-of-change, or probability percentage table, was derived from the statistical counts for each distress rating or score class.

The prediction tables in this chapter have shaded diagonals, indicating the probability that a current distress rating or score class will remain the same for the next year. Each row of the prediction table accumulates to 100 percent. This guarantees that the current distress rating or score class for the current year is properly distributed throughout each level.

Multi-year predictions of future PES distress ratings and score classes were extrapolated using the probability percentage tables. Plots of the multiple year rate-of-change were made from the extrapolated values. These plots are easier to interpret than a table of numbers.

The plots of the extrapolated distress ratings or score classes in this chapter **should not** be directly compared to the plots in Chapter 4. The plots in Chapter 4 are comparisons of multi-year random sample data, and **do not** compare the same survey sections of consecutive years.

For additional detailed information on the analysis procedure, please contact the Pavement Management section.

-Notes-

ASPHALT PAVEMENT (ACP) CONDITION PREDICTION

The predicted future values for pavement condition appear in Table 5.1a. The pavement condition classes are the same as those found in Table 4.1.

TABLE 5.1a -- ACP Prediction Values for Pavement Condition.

Current Condition Class	Predicted Condition Class				
	"A"	"B"	"C"	"D"	"F"
"A"	74.68%	17.58%	5.67%	1.32%	0.75%
"B"	47.91%	29.54%	15.56%	4.81%	2.18%
"C"	39.56%	23.76%	22.09%	9.59%	5.00%
"D"	36.84%	17.90%	20.62%	13.05%	11.59%
"F"	35.22%	14.72%	15.14%	12.96%	21.96%

Table 5.1 indicates that 74.68% of the mileage in condition class "A" will remain in class "A" for the next year. The remaining current class "A" mileage (25.32%) will worsen into classes "B" through "F" (at the rates of 17.58%, 5.67%, 1.32%, and 0.75%, respectively). The other current pavement condition class categories ("B", "C", "D", and "F") will change in a similar manner over the next year.

Beginning with the current (1990) percentage values for each pavement condition class (Figure 4.8) and using the condition class prediction table (Table 5.1), the first year's (1991) prediction values for condition class can be computed. Using the first year's prediction values and the condition class prediction table again, the second year's (1992) condition class prediction values can be derived. This iterative process continues producing a multiple year condition class extrapolation of predictions. The values for the most recent conditions have been extrapolated for the five year period, 1991 to 1995. These values appear in Table 5.1b and in Figure 5.1.

TABLE 5.1b -- ACP Predictions for Pavement Condition.

Year	Predicted Condition Class				
	"A"	"B"	"C"	"D"	"F"
1990 (current)	65.37%	20.97%	9.20%	2.75%	1.71%
1991	64.12%	20.62%	9.83%	3.33%	2.10%
1992	63.62%	20.60%	10.02%	3.49%	2.27%
1993	63.43%	20.61%	10.09%	3.54%	2.33%
1994	63.36%	20.61%	10.12%	3.56%	2.35%
1995	63.33%	20.61%	10.12%	3.57%	2.36%

Figure 5.1 shows that pavement condition on Texas highways will deteriorate slightly during the next five years, with all of the deterioration occurring in classes "A" and "B".

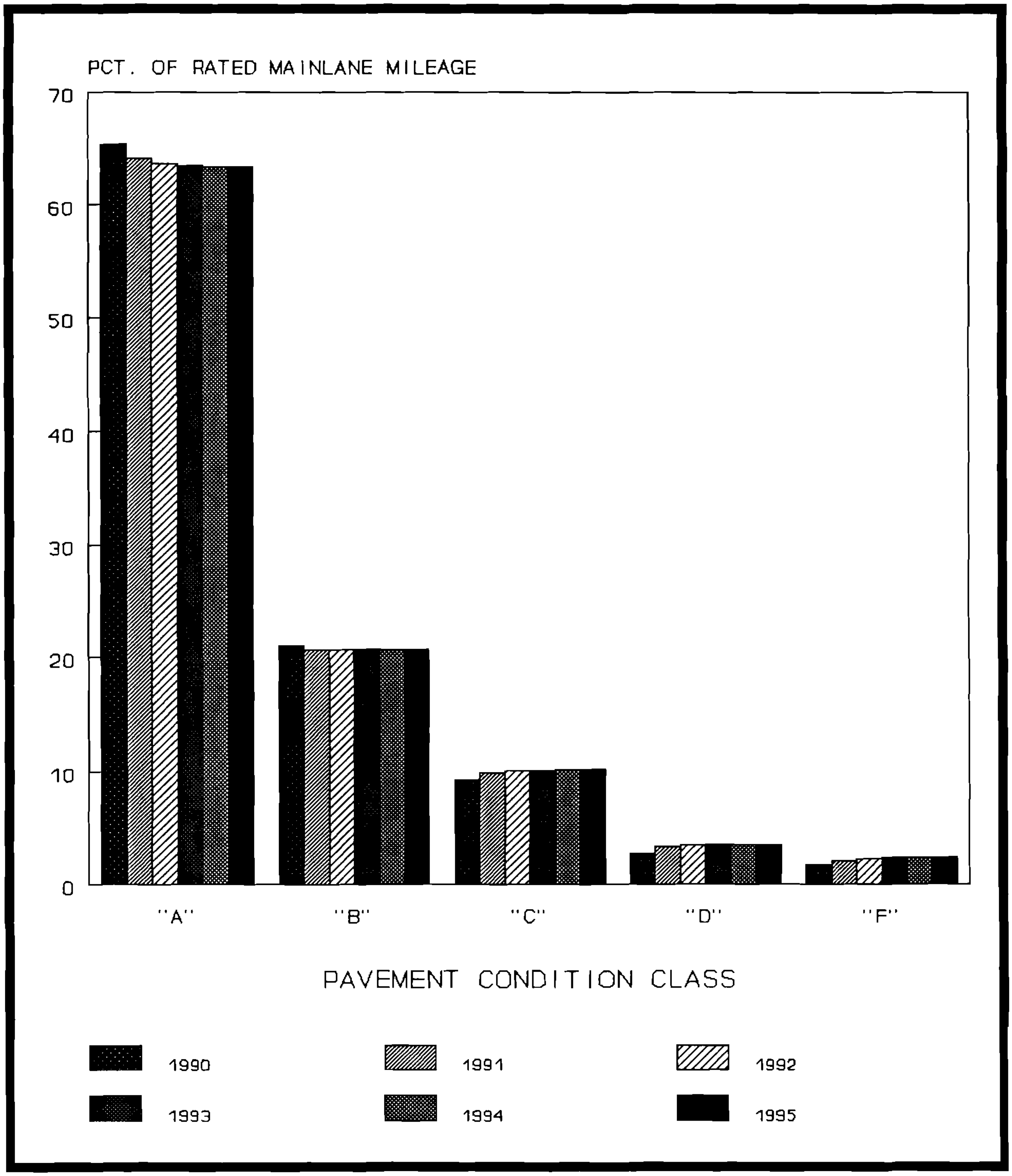


Figure 5.1 -- Condition Prediction of ACP 1991-1995.

ACP RIDE QUALITY PREDICTION

The prediction values for ride quality appear in Table 5.2 using the classes described in Table 4.2.

Table 5.2 -- ACP Prediction Values for Ride Quality.

Current Ride Quality Class	Predicted Ride Quality Class				
	"A"	"B"	"C"	"D"	"F"
"A"	73.42%	25.12%	1.25%	0.16%	0.05%
"B"	28.78%	62.64%	8.38%	0.18%	0.02%
"C"	6.05%	39.81%	50.29%	3.83%	0.02%
"D"	3.14%	9.08%	51.08%	35.72%	0.98%
"F"	9.59%	20.55%	15.07%	39.72%	15.07%

Table 5.2 was developed in a similar manner as Table 5.1.

The ride quality prediction table (Table 5.2) suggests that 73.42% of the mileage in ride quality class "A" will remain in class "A" for the next year. The remaining percentage of class "A" ride quality (26.58%) will primarily change to class "B" (25.12%). Only a very small amount of class "A" mileage will drop to classes "C" through "F" (1.25%, 0.16%, and 0.05%, respectively). The remaining current year ride quality classes ("B", "C", "D", and "F") suggest a similar change for the next year.

As shown in Figure 5.2, the overall ride quality on Texas highways is expected to increase in the next five years. Almost all of the ride quality increase occurs in class "A". The sections with the largest decrease in percentages of ride quality are classes "B" and "C".

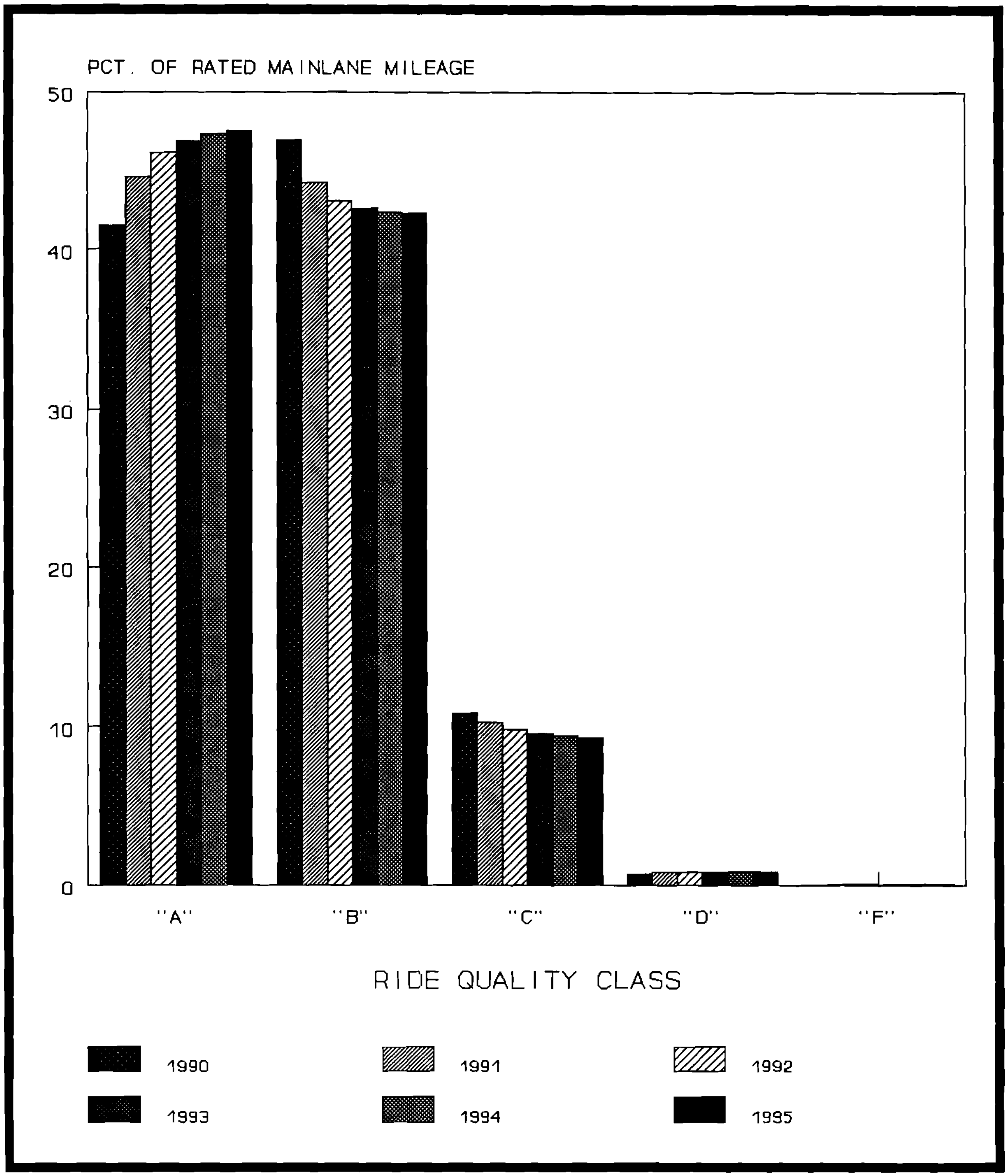


Figure 5.2 -- Ride Quality Prediction of ACP 1991-1995.

ACP Distress Prediction

The prediction values for pavement distress appear in Table 5.3. The pavement distress classes are the same as those in Table 4.3.

Table 5.3 -- ACP Prediction Values for Pavement Distress.

Current Distress Class	Predicted Distress Class				
	"A"	"B"	"C"	"D"	"F"
"A"	75.02%	10.48%	7.12%	3.38%	4.00%
"B"	51.37%	16.42%	12.19%	8.79%	11.23%
"C"	46.60%	13.68%	16.40%	9.12%	14.20%
"D"	42.77%	11.18%	12.71%	12.19%	21.15%
"F"	43.48%	8.42%	10.05%	9.60%	28.45%

Table 5.3 was developed in a similar manner as Table 5.1.

Of the current class "A" pavement distress mileage, 24.98% will worsen, while 75.02% will remain unchanged. The majority of the deteriorated class "A" mileage will drop into classes "B" and "C" (10.48% and 7.12%, respectively). A small percentage (7.38%) will drop into classes "D" and "F" (3.38% and 4.00%, respectively). The remaining current year pavement condition classes ("B", "C", "D", and "F") will change in a similar manner next year.

Figure 5.3 shows that the amount of class "A" mileage will deteriorate significantly over the next five years. Class "B" mileage will also drop, but only slightly. Although the class "C" will increase, the majority will be in the class "F" mileage. Class "D" mileage will remain mostly unchanged.

Figure 5.3 shows that the overall pavement distress on Texas highways is expected to increase in the next five years, with all of the deterioration occurring in classes "A" and "B".

Prediction of Individual Distress Types

Increases in the amount of ACP distress over the next five years may be traced to predicted increases in the amount of load-associated distress. The following pages describes the predicted changes in each of the seven ACP distress types.

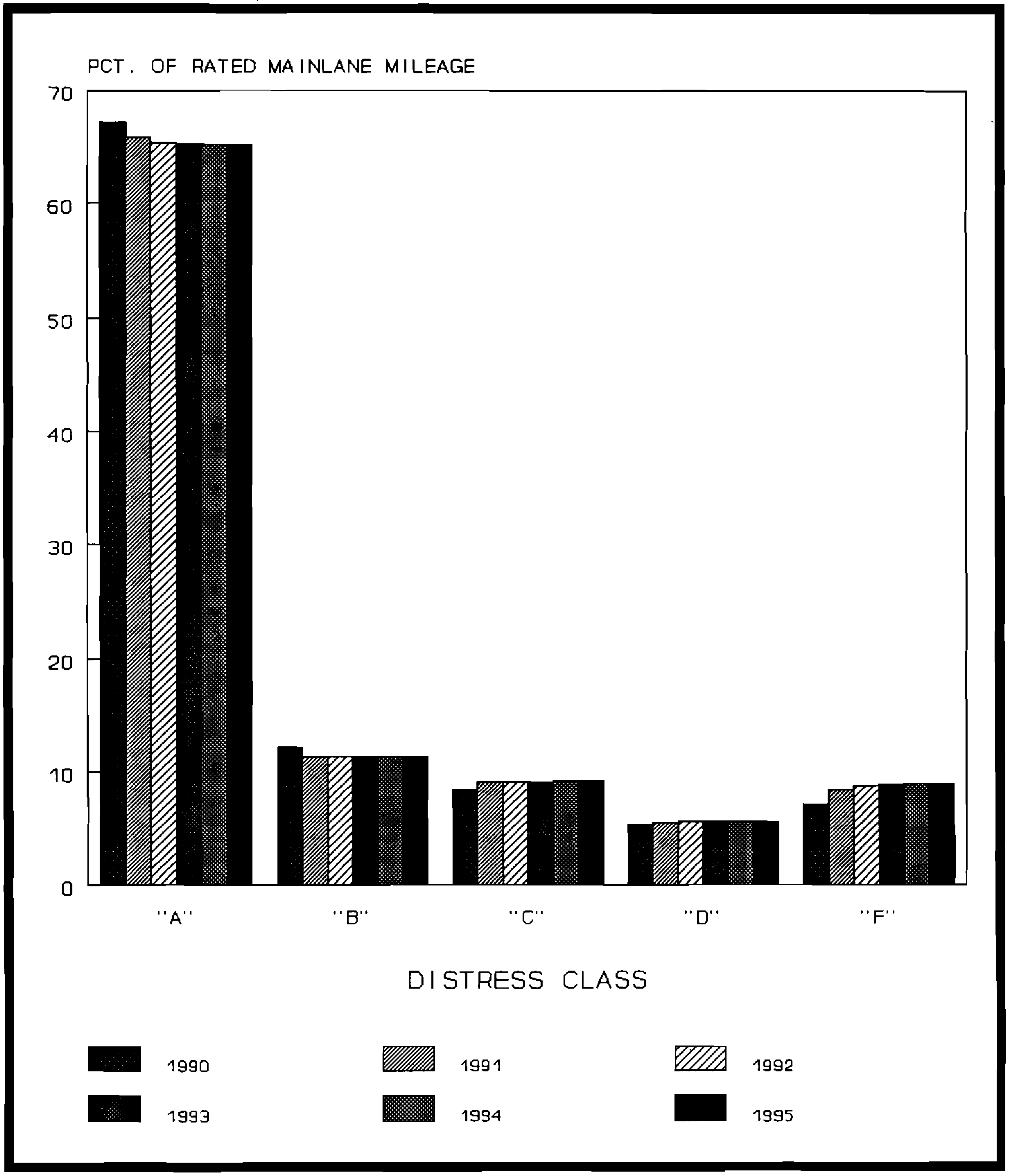


Figure 5.3 -- Distress Prediction of ACP 1991-1995.

Rutting

The prediction values for rutting appear in Table 5.4. The rutting categories are the same as those in the "1991 Pavement Evaluation System Rater's Manual".

Table 5.4 -- Rutting Prediction Values for ACP.

Current Rutting (area, depth)	Predicted Rutting (area, depth)						
	0%, 0"	1-25%, ½-1"	26-50%, ½-1"	1-25%, >1"	>50%, ½-1"	26-50%, >1"	>50%, >1"
0%, 0"	79.22%	16.62%	2.58%	0.79%	0.55%	0.22%	0.02%
1-25%, ½-1"	47.89%	37.14%	7.97%	4.45%	1.28%	1.18%	0.09%
26-50%, ½-1"	39.38%	32.03%	15.68%	5.36%	4.44%	2.73%	0.38%
1-25%, >1"	31.62%	33.51%	9.21%	19.24%	1.51%	4.53%	0.38%
>50%, ½-1"	34.81%	22.14%	18.32%	2.59%	17.10%	4.12%	0.92%
26-50%, >1"	28.66%	31.15%	11.35%	14.23%	1.73%	10.19%	2.69%
>50%, >1"	32.14%	23.22%	16.07%	8.93%	3.57%	8.93%	7.14%

Table 5.4 was developed in a similar manner as Table 5.1.

Table 5.4 indicates that 79.22% of the mileage with no rutting (0%, 0") will have no rutting in the next year. Almost all (16.62%) of the remaining mileage will have ½-1" deep ruts over 1-25% area. Only a very small amount (0.79%, 0.22%, and 0.02%) will develop ruts greater than 1" deep in the next year.

Figure 5.4 shows that as the ACP mileage ages, the amount of ½-1" deep rutting (1-25%, 26-50%, and >50%) will increase. However, the amount of "severe" rutting (>1" deep) will stay about the same.

Thus, the overall amount of rutting on Texas highways is expected to increase during the next five years.

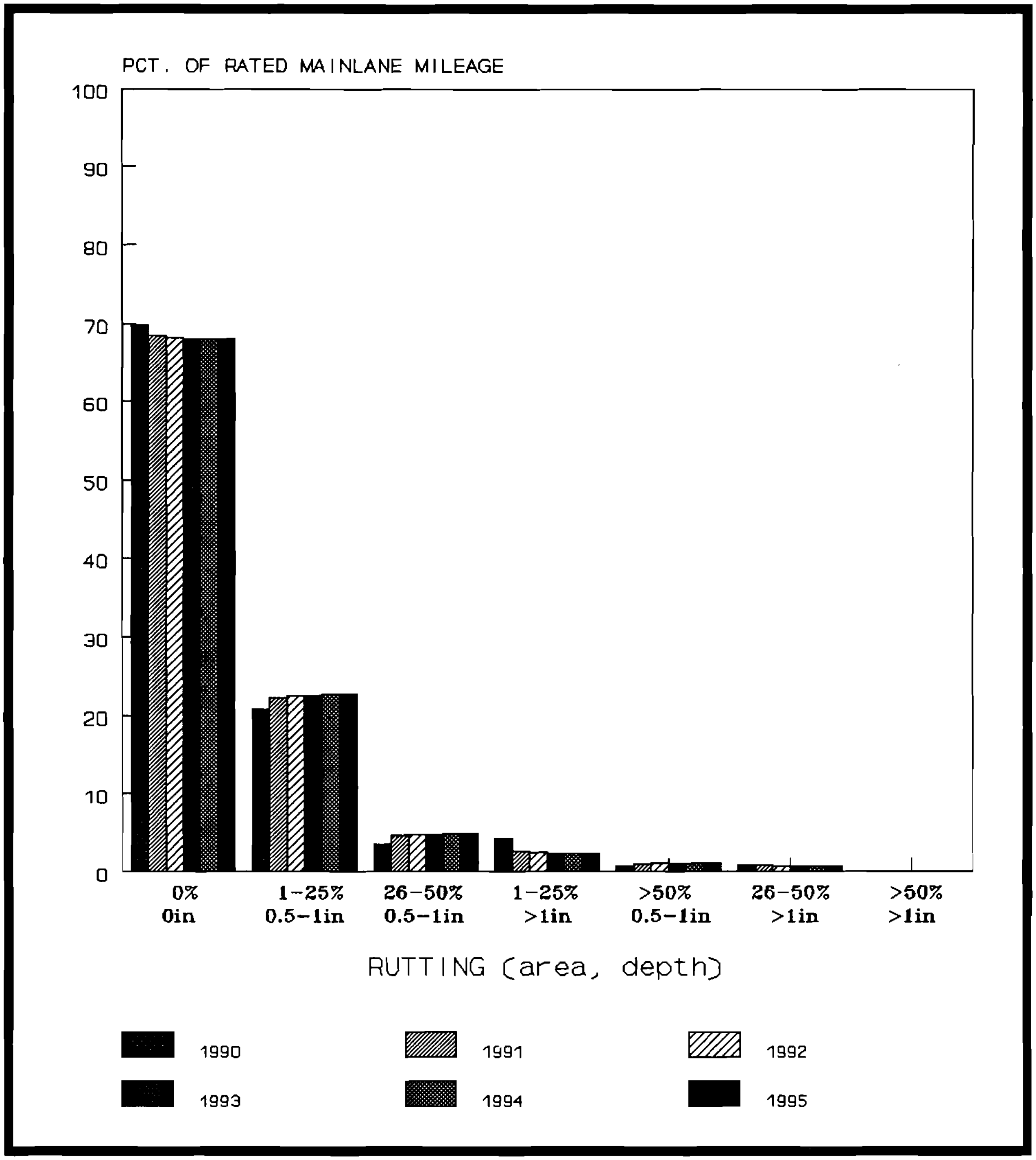


Figure 5.4 -- Rutting Prediction for ACP 1991-1995.

Patching

The prediction values for patching appear in Table 5.5. The patching categories are the same as those in the "1991 Pavement Evaluation System Rater's Manual".

Table 5.5 -- Patching Prediction Values for ACP.

Current Patching (area)	Predicted Patching (area)			
	0%	1-10%	11-50%	>50%
0%	83.30%	12.80%	3.18%	0.72%
1-10%	54.25%	33.00%	11.15%	1.60%
11-50%	50.00%	21.63%	23.96%	4.41%
>50%	59.49%	12.51%	13.64%	14.36%

The prediction values for Table 5.5 were derived in a similar manner as those in Table 5.1.

In any given year, 83.30% of the mileage with no patching will have no patching in the next year (Table 5.5). Of the remaining 16.70% which are patched in the next year, 12.80% will have only slight (1-10%) patching, 3.18% will have moderate (11-50%) patching, and only 0.72% will have severe (>50%) patching.

Figure 5.5 indicates that the amount of patching on Texas highways is expected to increase during the next five years. This increase should be directly related to a decrease in one or more of the cracking distress types.

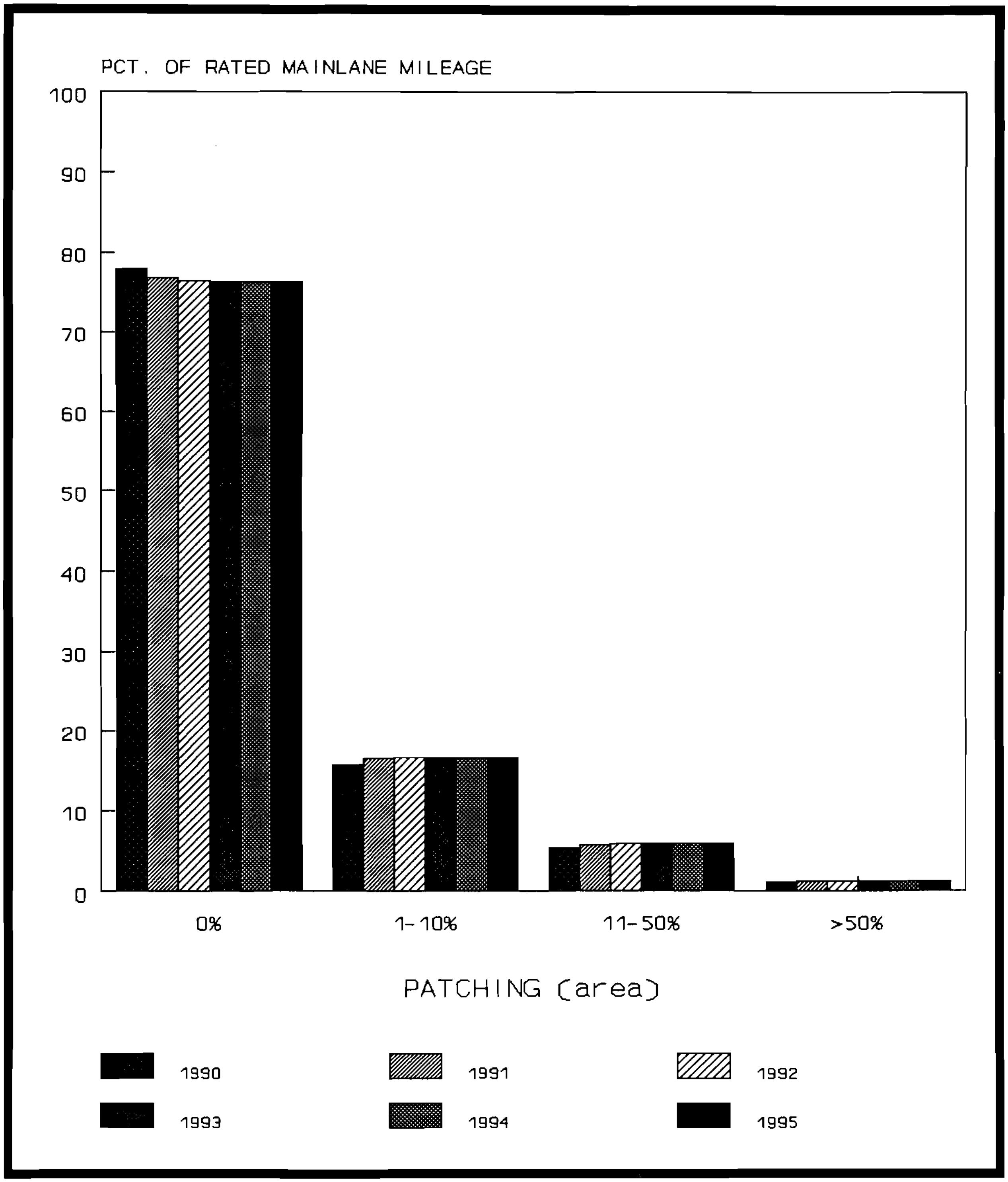


Figure 5.5 -- Patching Prediction for ACP 1991-1995.

Failures

The prediction values for failures appear in Table 5.6. The categories for failures are the same as those in the "1991 Pavement Evaluation System Rater's Manual".

Table 5.6 -- Failure Prediction Values for ACP.

Current Failures (per mile)	Predicted Failures (per mile)			
	0	1-5	6-10	>10
0	96.31%	3.35%	0.23%	0.11%
1-5	75.91%	20.44%	2.54%	1.11%
6-10	64.08%	23.27%	10.20%	2.45%
>10	68.00%	14.00%	5.00%	13.00%

Table 5.6 was derived in a similar manner as Table 5.1.

In any given year, 96.31% of the mileage with no failures will have no failures in the next year (Table 5.6). Of the remaining 3.69% which will contain failures the next year, 3.35% will have only a slight (1-5 per mile) number of failures, 0.23% will have a moderate (6-10 per mile) number of failures, and only 0.11% will have a severe (>10 per mile) number of failures.

As shown in Figure 5.6, the amount of failures on Texas highways is expected to increase, but only slightly, during the next five years.

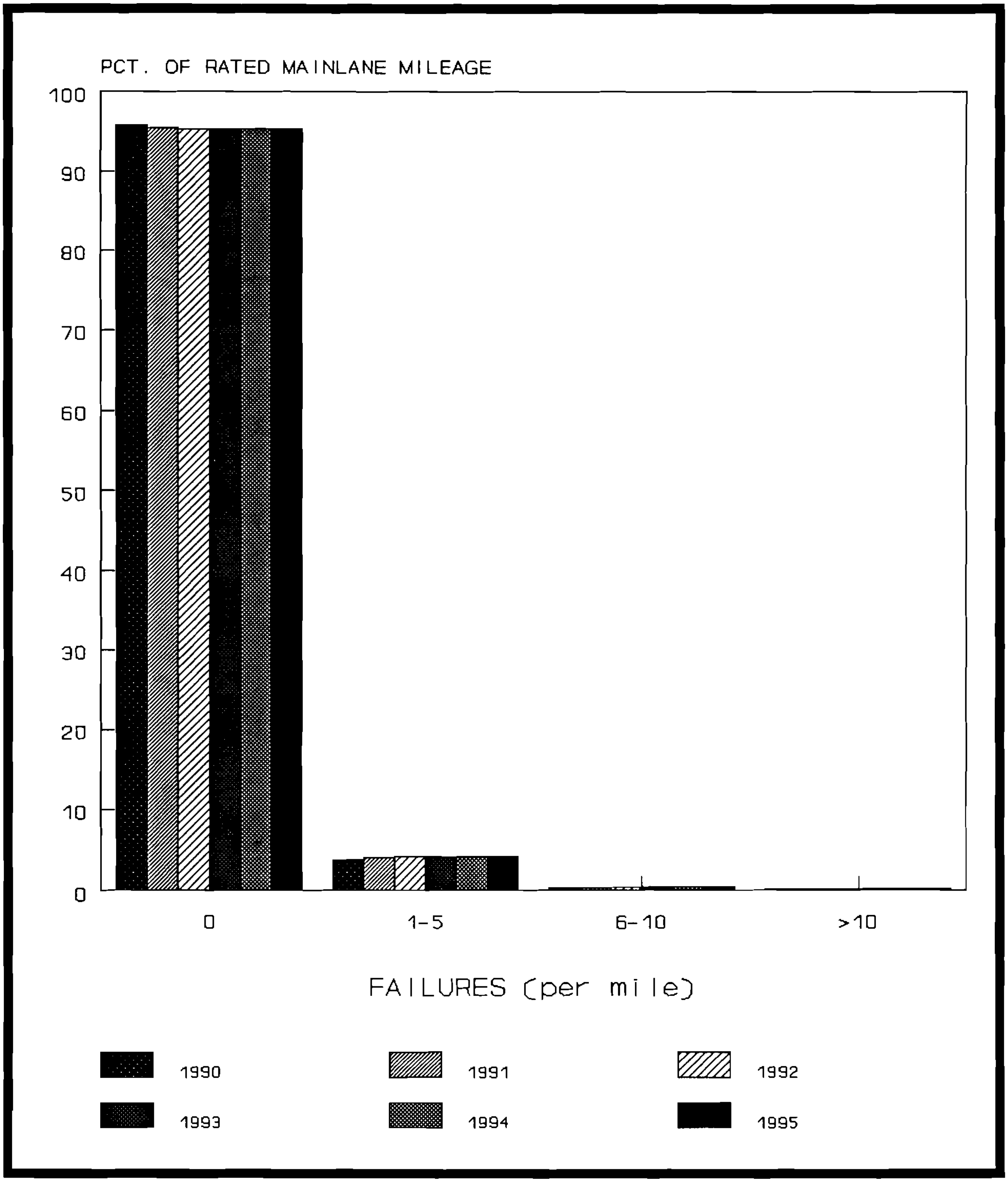


Figure 5.6 -- Failure Prediction for ACP 1991-1995.

Block Cracking

The block cracking prediction values appear in Table 5.7. The categories for block cracking are the same as those in the "1991 Pavement Evaluation System Rater's Manual".

Table 5.7 -- Block Cracking Prediction Values for ACP.

Current Block Cracking (area)	Predicted Block Cracking (area)			
	0%	1-10%	11-50%	>50%
0%	96.18%	2.49%	0.96%	0.37%
1-10%	79.35%	12.04%	6.41%	2.20%
11-50%	67.35%	13.19%	12.76%	6.70%
>50%	67.97%	8.56%	10.51%	12.96%

Table 5.7 was created in a similar manner as Table 5.1.

In any given year, 96.18% of the mileage with no block cracking will have no block cracking in the next year (Table 5.7). Of the remaining 3.82% which will have block cracking in the next year, 2.49% will have only slight (1-10%) block cracking, 0.96% will have moderate (11-50%) block cracking, and only 0.37% will have severe (>50%) block cracking.

Figure 5.7 shows that the overall amount of block cracking on Texas highways will increase slightly during the next five years, with almost all of the increase occurring in the slight (1-10%) and moderate (11-50%) groups.

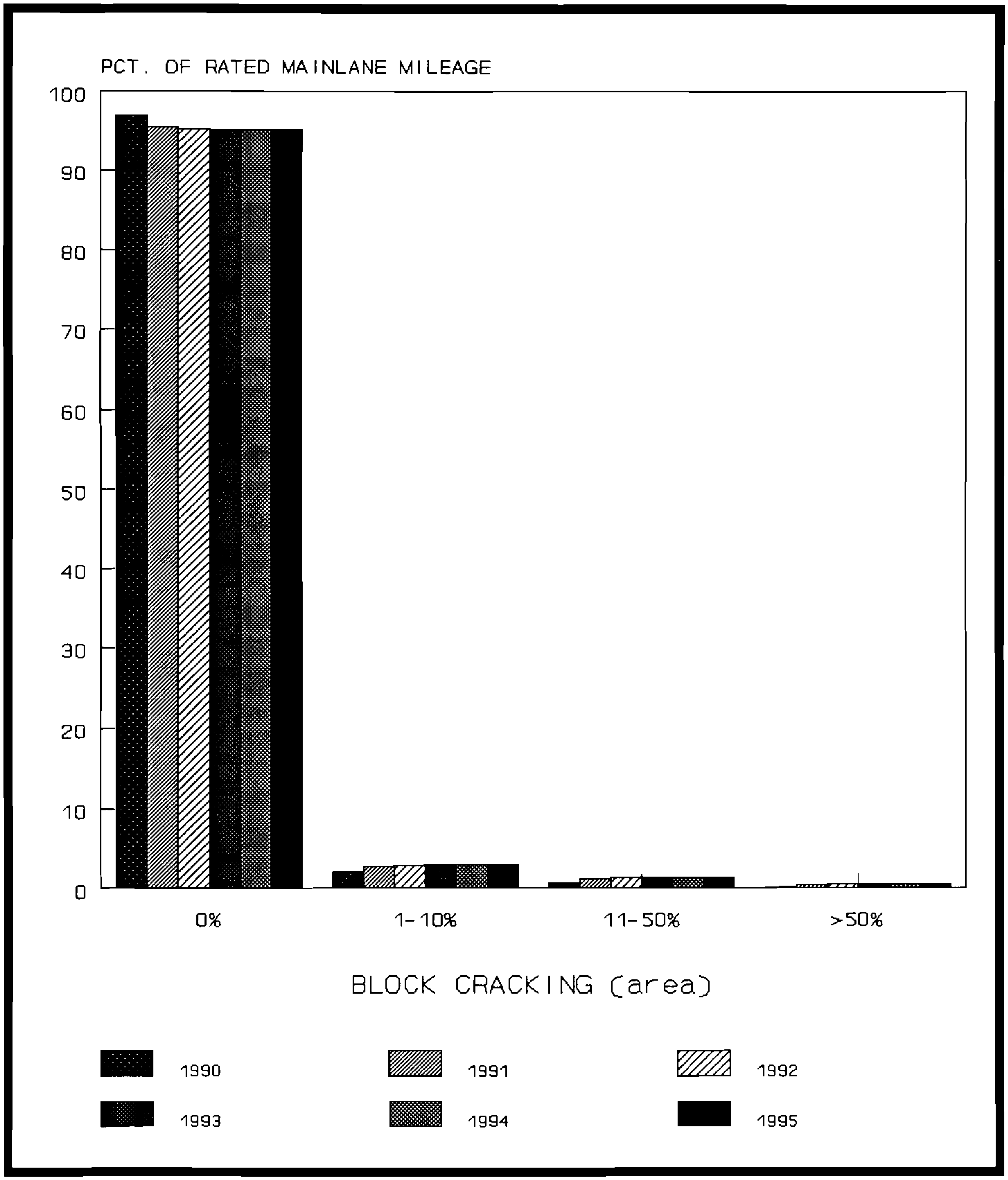


Figure 5.7 -- Block Cracking Prediction for ACP 1991-1995.

Alligator Cracking

The alligator cracking prediction values appear in Table 5.8. The alligator cracking categories are the same as those found in the "1991 Pavement Evaluation System Rater's Manual".

Table 5.8 -- Alligator Cracking Prediction Values for ACP.

Current Alligator Cracking (area)	Predicted Alligator Cracking (area)			
	0%	1-10%	11-50%	>50%
0%	**91.31%**	6.93%	1.51%	0.25%
1-10%	67.56%	**23.50%**	7.65%	1.29%
11-50%	61.04%	17.68%	**16.45%**	4.83%
>50%	59.64%	10.82%	14.56%	**14.98%**

Table 5.8 was derived in a similar manner as Table 5.1

In any given year, 91.31% of the mileage with no alligator cracking will have no alligator cracking in the next year (Table 5.8). Of the remaining 8.69% which will contain alligator cracking in the next year, 6.93% will have only slight (1-10%) alligator cracking, 1.51% will have moderate (11-50%) alligator cracking, and only 0.25% will have severe (>50%) alligator cracking.

Figure 5.8 shows that the overall amount of alligator cracking on Texas highways will increase slightly during the next five years, with almost all of the increase occurring in the slight (1-10%) and moderate (11-50%) groups.

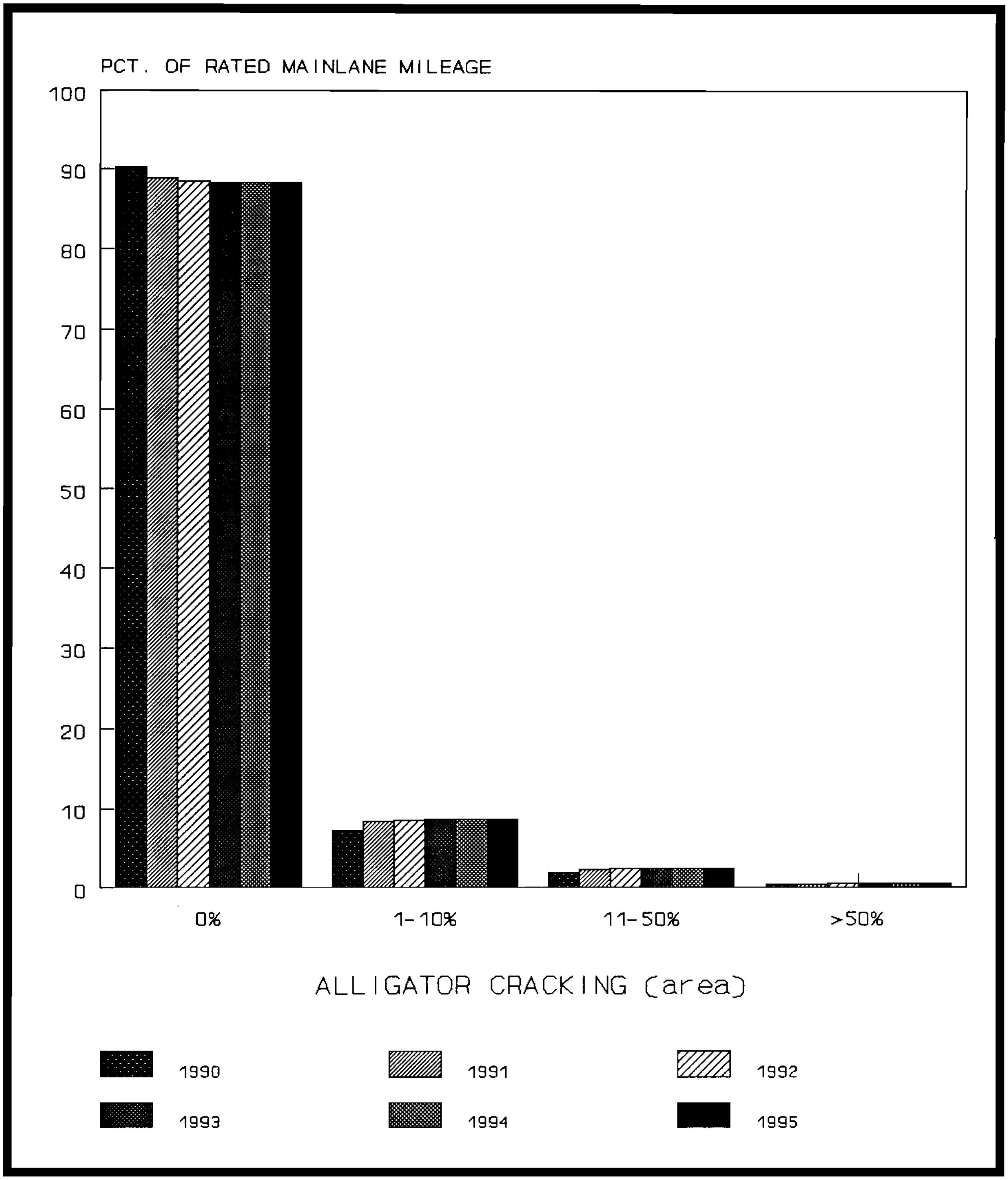


Figure 5.8 -- Alligator Cracking Prediction for ACP 1991-1995.

Longitudinal Cracking

Table 5.9 displays the longitudinal cracking prediction values. The longitudinal cracking categories are the same as those in the "1991 Pavement Evaluation System Rater's Manual".

Table 5.9 -- Longitudinal Cracking Prediction Values for ACP.

Current Longitudinal Cracking (linear ft)	Predicted Longitudinal Cracking (linear ft)			
	0	10-99	100-200	>200
0	81.45%	16.69%	1.59%	0.27%
10-99	47.74%	41.54%	9.28%	1.44%
100-200	38.99%	36.71%	19.98%	4.32%
>200	44.37%	27.10%	21.40%	7.13%

Table 5.9 was derived in the same manner as Table 5.1.

In any given year, 81.45% of the mileage with no longitudinal cracking will have no longitudinal cracking in the next year (Table 5.9). Of the remaining 18.55% which will contain longitudinal cracking in the next year, 16.69% will have only slight (11-99' per station) longitudinal cracking, 1.59% will have moderate (100-200' per station) longitudinal cracking, and only 0.27% will have severe (>200' per station) longitudinal cracking.

Figure 5.9 shows that the overall amount of longitudinal cracking on Texas highways will decrease over the next five years. However, the amount of moderate (100-200' per station) and severe (>200' per station) longitudinal cracking is expected to increase slightly.

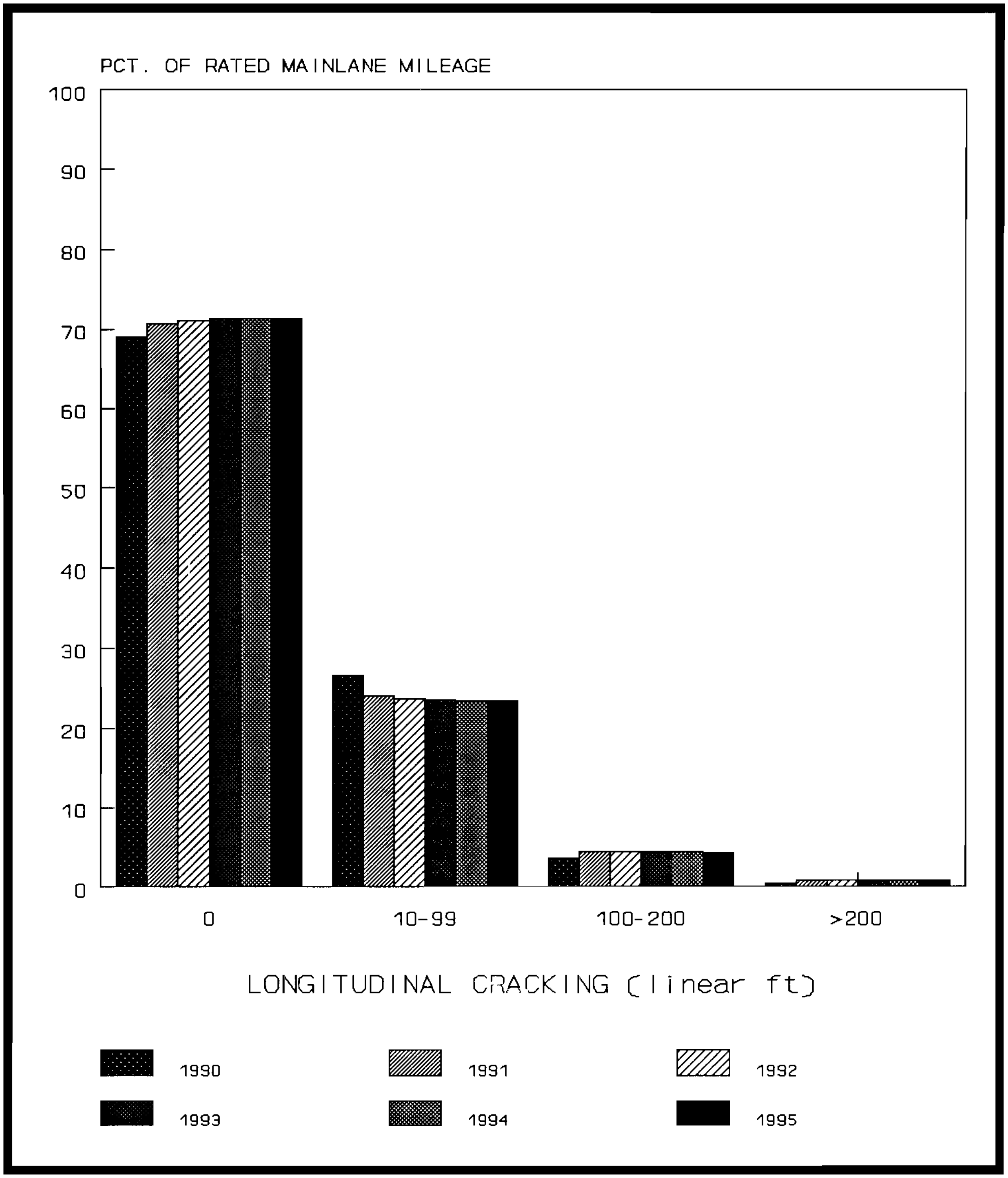


Figure 5.9 -- Longitudinal Cracking Prediction for ACP 1991-1995.

Transverse Cracking

The prediction values for transverse cracking appear in Table 5.10. The transverse cracking categories are the same as those in the "1991 Pavement Evaluation System Rater's Manual".

Table 5.10 -- Transverse Cracking Prediction Values for ACP.

Current Transverse Cracking (no. per station)	Predicted Transverse Cracking (no. per station)			
	0	1-4	5-10	>10
0	86.63%	11.27%	1.75%	0.35%
1-4	43.21%	41.21%	13.18%	2.40%
5-10	35.07%	34.39%	24.88%	5.66%
>10	36.81%	28.12%	25.48%	9.59%

Table 5.10 was created in a similar manner as Table 5.1.

In any given year, 86.63% of the mileage with no transverse cracking will have no transverse cracking in the next year (Table 5.10). Of the remaining 13.37% which will contain transverse cracking in the next year, 11.27% will have only slight (1-4 per station) transverse cracking, 1.75% will have moderate (5-10 per station) transverse cracking, and only 0.35% will have severe (>10 per station) transverse cracking.

Figure 5.10 shows that the overall amount of transverse cracking on Texas highways will decrease over the next five years. However, the amount of moderate (5-10 per station) and severe (>10 per station) transverse cracking is expected to increase slightly.

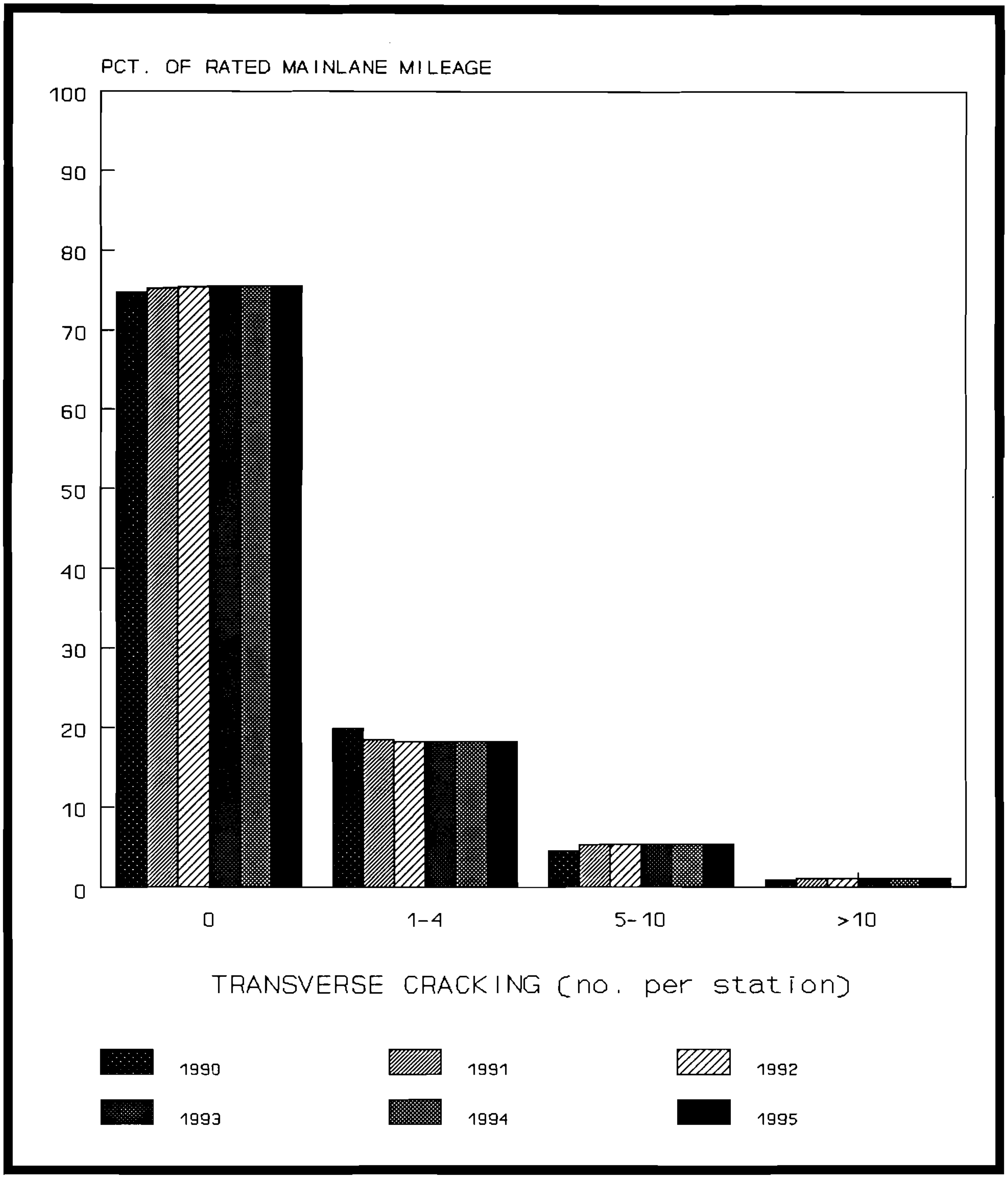


Figure 5.10 -- Transverse Cracking Prediction for ACP 1991-1995.

Summary of Estimated Future Conditions (1991-1995)

A noticeable increase in asphalt pavement distress will lower the statewide ACP distress scores over the next five years. Load-related distresses, such as rutting, failures, and alligator cracking will cause most of the drop in distress score.

Even though ACP ride quality will improve substantially, increasing amounts of pavement distress will cause an overall drop in statewide ACP condition over the next five years. This demonstrates that ride quality, although extremely important from a public service standpoint, cannot necessarily be used as the sole measure of overall pavement condition.

CHAPTER 6
STATEWIDE PAVEMENT REHABILITATION NEEDS

PES' statewide pavement rehabilitation estimates are based on rated mainlane mileage that urgently needs care. Pavement Score (PS), which is also called Rehab Priority score is used to make these determinations. PS ranges from 1 (urgent need for rehab) to 100 (no rehab needed), with pavement sections below 35, needing rehabilitation or reconstruction. Table 6.1 suggests actions for different PS.

TABLE 6.1 -- Treatments for Rehab Priority Score.

PS	CLASS	PRIORITY		
		Preventive Maintenance	Routine Maintenance	Rehab/ Reconstruction
90-100	"A"	HIGH	N/A	N/A
70-89	"B"	HIGH	LOW	N/A
50-69	"C"	MODERATE	HIGH	LOW
35-49	"D"	LOW	MODERATE	MODERATE
1-34	"F"	N/A	N/A	HIGH

The rehabilitation model extrapolates the mainlane mileage in need of immediate rehabilitation from the PES statistical sample. This sample is representative of the Texas highway network. Highway sections are stratified into the following four classes for analysis:

1. 24 - Districts (1-25, except 22)
2. 4 - Highway Systems (IH, US, SH, or FM)
3. 3 - Pavement Types (ACP, CRC, or JCP)
4. 3 - Average Daily Traffic -- ADT Classes (1, 2, or 3)

These classes partition the Texas highway network into 864 (24 x 4 x 3 x 3) pavement section groups. Each group is considered independently, with the results assembled into major categories for reporting.

Construction sections (which could not be rated) and frontage roads are eliminated from each group before the extrapolation is performed. Table 6.2 lists the PES mainlane inventory mileage by pavement type and highway system, by year, from 1986-1990. This table includes sections under construction during the time of the survey.

TABLE 6.2 -- Assumed Total Statewide Mainlane Mileage 1986-1990.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	ALL
1986	ACP	9,180	32,003	33,581	81,438	156,202
	CRC	3,640	1,158	817	84	5,699
	JCP	1,445	1,176	1,336	355	4,312
	TOTAL	14,265	34,337	35,734	81,877	166,213
1987	ACP	9,449	32,010	34,091	81,747	157,298
	CRC	3,425	1,055	683	86	5,249
	JCP	1,407	1,115	1,266	356	4,144
	TOTAL	14,282	34,180	36,040	82,189	166,691
1988	ACP	9,758	32,189	34,391	81,554	157,892
	CRC	3,587	1,086	868	66	5,606
	JCP	1,219	1,110	1,307	368	4,004
	TOTAL	14,563	34,385	36,566	81,988	167,503
1989	ACP	9,696	31,831	34,426	82,341	158,294
	CRC	3,516	1,113	762	82	5,474
	JCP	1,068	1,015	1,221	343	3,646
	TOTAL	14,280	33,959	36,409	82,766	167,414
1990	ACP	9,856	31,854	34,417	80,829	156,955
	CRC	3,670	1,144	683	120	5,617
	JCP	1,100	1,034	939	325	3,397
	TOTAL	14,625	34,032	36,038	81,273	165,969

NOTES: Frontage roads are not included in this table since frontage road mileage is not directly available from PES data files. Totals may not be exact due to roundoff error.

The estimated lane mileage in need of rehabilitation is then multiplied by an assumed unit treatment cost. The cost for a typical rehabilitation treatment is based on highway system, pavement type, and ADT class. Table 6.3 indicates the treatment cost by lane mile. These treatments do not consider effects of inflation, so a year-by-year comparison is possible. These costs simulate intensive rehabilitation or reconstruction work, but do not represent all rehabilitation strategies done in the Districts. Because of the different unit treatment costs, funding and mileage estimates do not have a one-to-one correlation.

TABLE 6.3 -- Assumed 1986-1990 Pavement Rehabilitation Cost (in Dollars per Lane Mile).

PAVEMENT TYPE	IH		US/SH		FM	
	COST	ADT	COST	ADT	COST	ADT
ACP	$85,000	23,000	$65,000	23,000	$25,000	1,500
	$143,000	100,000	$143,000	100,000	$50,000	+1,500
	$400,000	+100,000	$400,000	+100,000		
CRC	$103,000	25,000	$103,000	25,000	$25,000	1,500
	$143,000	100,000	$143,000	100,000	$50,000	+1,500
	$400,000	+100,000	$400,000	+100,000		
JCP			$65,000	25,000	$25,000	1,500
	$165,000	100,000	$165,000	100,000	$50,000	+1,500
	$500,000	+100,000	$500,000	+100,000		

NOTE: ADT is Average Daily Traffic, in vehicles per day.

Table 6.4 lists the statewide mainlane mileage in need of immediate rehabilitation from 1986-1990 by pavement type and highway system. The amount of mileage needing rehabilitation in the last five years has decreased from 11,865 miles in 1986 to 6,921 miles in 1990. The largest drop in rehabilitation mileage was between 1987 and 1988, when the mileage needs dropped from 11,236 miles to 8,053 miles. In 1989, another modest drop occurred in rehabilitation needs. The 1990 needs remain about the same as 1989 at 6,921. The only highway system to show an increase in mileage each year since 1988 has been the Interstate system. The US system has remained stable since 1988, while the FM and SH have dropped slightly in needs. Figures 6.1 and 6.2 are graphical representations of mileage in need of rehabilitation, by pavement type and highway system, respectively.

TABLE 6.4 -- Total Projected Statewide Lane Mileage in Need of Rehabilitation 1986-1990.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	ALL
1986	ACP	286	1,692	2,076	4,848	8,902
	CRC	768	307	202	2	1,279
	JCP	422	502	605	155	1,684
	TOTAL	1,476	2,501	2,883	5,005	11,865
1987	ACP	490	1,897	1,845	5,397	9,629
	CRC	176	375	3	0	554
	JCP	387	343	281	42	1,053
	TOTAL	1,053	2,615	2,129	5,439	11,236
1988	ACP	294	1,259	1,355	3,809	6,717
	CRC	170	106	35	0	311
	JCP	212	245	457	111	1,025
	TOTAL	676	1,610	1,847	3,920	8,053
1989	ACP	261	1,192	1,096	2,939	5,488
	CRC	470	312	138	0	920
	JCP	130	157	372	9	668
	TOTAL	861	1,661	1,606	2,948	7,076
1990	ACP	270	1,082	839	2,724	4,915
	CRC	524	241	121	0	886
	JCP	171	318	441	190	1,120
	TOTAL	965	1,641	1,401	2,914	6,921

NOTES: Frontage roads are not included in this table. Totals may not be exact due to roundoff error.

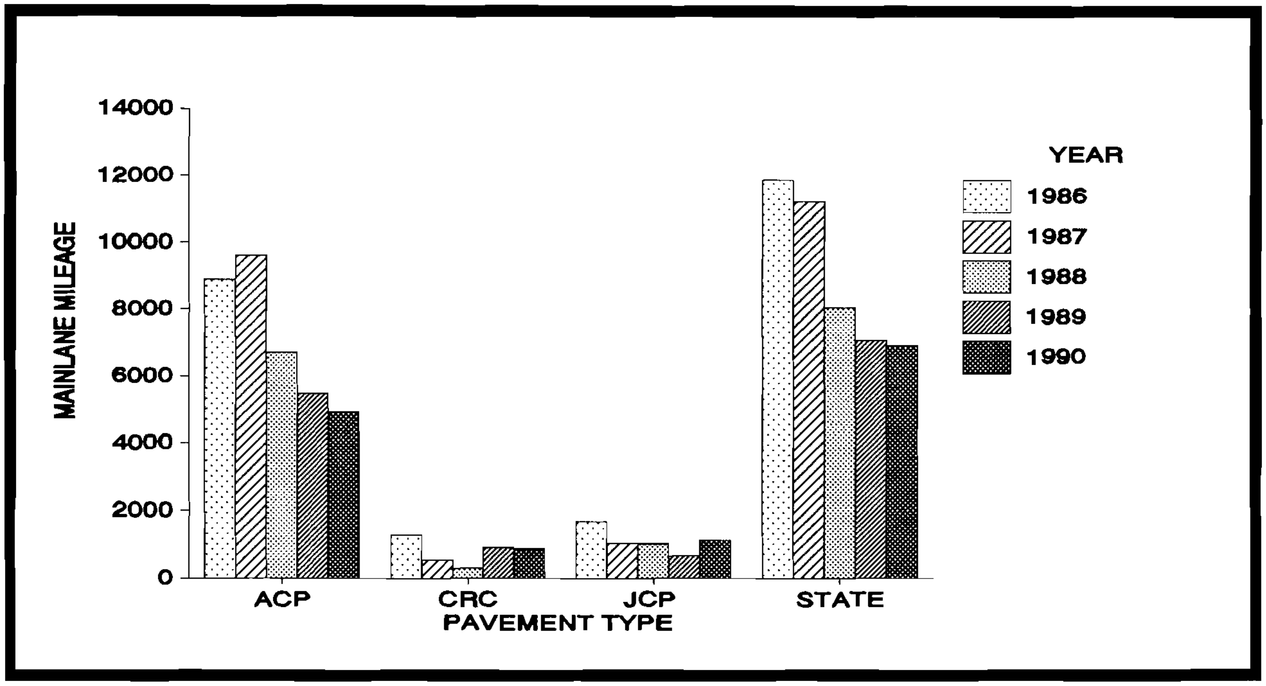


Figure 6.1 -- Estimated Mainlane Mileage In Need of Rehabilitation, by Pavement Type, 1986-1990.

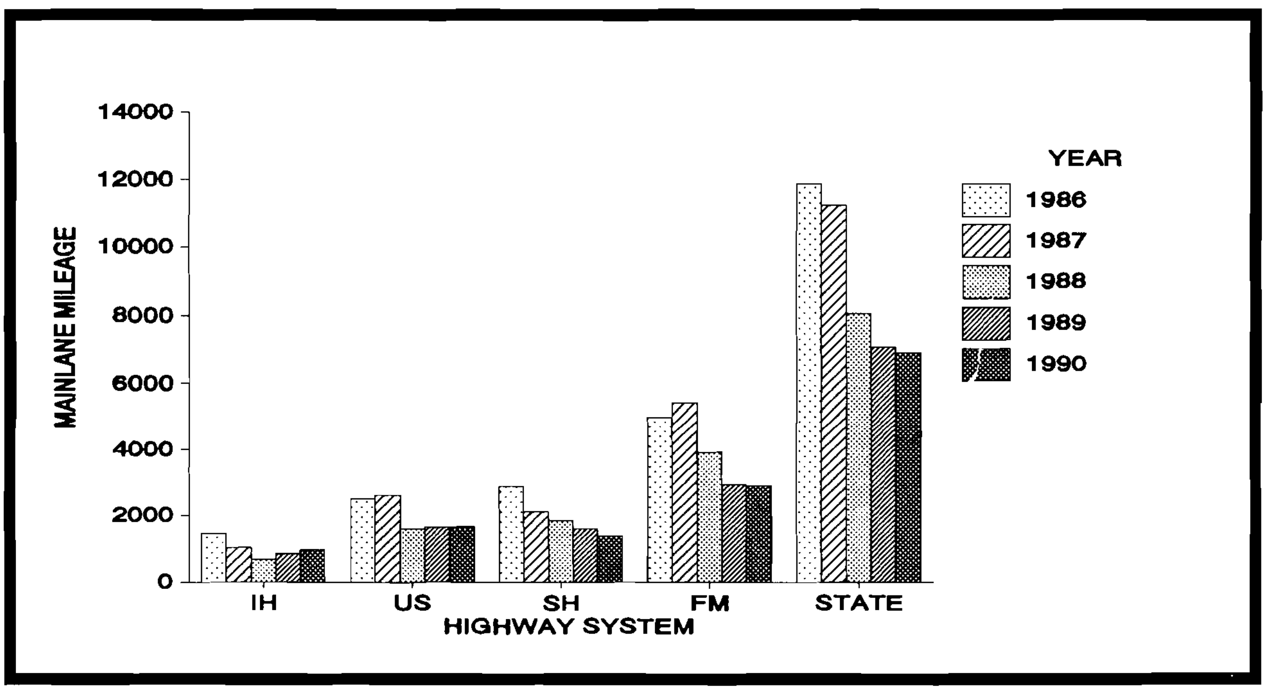


Figure 6.2 -- Estimated Mileage In Need of Rehabilitation, by System, 1986-1990.

Table 6.5 lists the rehabilitation funding needs from 1986-1990 by pavement type and highway system. The funding needs also have decreased each year from 1986-1990 with a large drop occurring between 1987 and 1988. The last three years have slowed in improvement with needs hovering around 500-550 million dollars. The SH system was the only system to decrease in needs the last two years while the US and FM systems have shown slight increases in funding needs. The IH system is a good example of mileage and funding not having a direct correlation. In 1990, mileage in need of rehabilitation went up, while funding needs went down. Figure 6.3 and 6.4 give graphical representation of rehabilitation funding needs from 1986-1990, by pavement type and highway system, respectively.

TABLE 6.5 -- Total Projected Statewide Pavement Rehabilitation Funding Requirements 1986-1990.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	ALL
1986	ACP	$33,784,428	$145,461,494	$150,108,942	$148,029,605	$477,384,469
	CRC	$159,100,382	$38,911,917	$24,952,287	$112,727	$223,077,313
	JCP	$69,591,633	$68,811,533	$58,742,917	$6,363,418	$203,509,501
	TOTAL	$262,476,443	$253,184,944	$233,804,146	$154,505,750	$903,971,283
1987	ACP	$50,881,209	$135,307,790	$137,599,931	$169,436,963	$493,225,893
	CRC	$23,950,121	$65,204,542	$357,067	$0	$89,511,730
	JCP	$154,613,807	$44,701,000	$18,746,375	$1,474,839	$219,536,021
	TOTAL	$229,445,137	$245,213,332	$156,703,373	$170,911,802	$802,273,644
1988	ACP	$40,374,402	$94,941,395	$102,185,415	$107,754,831	$345,256,043
	CRC	$32,551,348	$11,366,871	$4,469,253	$0	$48,387,472
	JCP	$65,827,298	$36,093,789	$44,828,030	$5,550,000	$152,299,117
	TOTAL	$138,753,048	$142,402,055	$151,482,698	$113,304,831	$545,942,632
1989	ACP	$33,473,321	$89,258,004	$88,527,829	$89,157,373	$300,416,527
	CRC	$99,076,314	$32,822,057	$19,751,333	$0	$151,649,704
	JCP	$27,987,450	$19,424,601	$39,814,383	$470,000	$87,696,434
	TOTAL	$160,537,085	$141,504,662	$148,093,545	$89,627,373	$539,762,665
1990	ACP	$31,674,533	$83,905,197	$61,647,571	$81,584,190	$258,811,491
	CRC	$78,664,887	$28,555,060	$17,984,795	$0	$125,204,742
	JCP	$38,924,116	$35,168,407	$45,245,987	$9,210,862	$128,549,372
	TOTAL	$149,263,536	$147,628,664	$124,878,353	$90,795,052	$512,565,605

NOTES: Frontage roads are not included in this table.

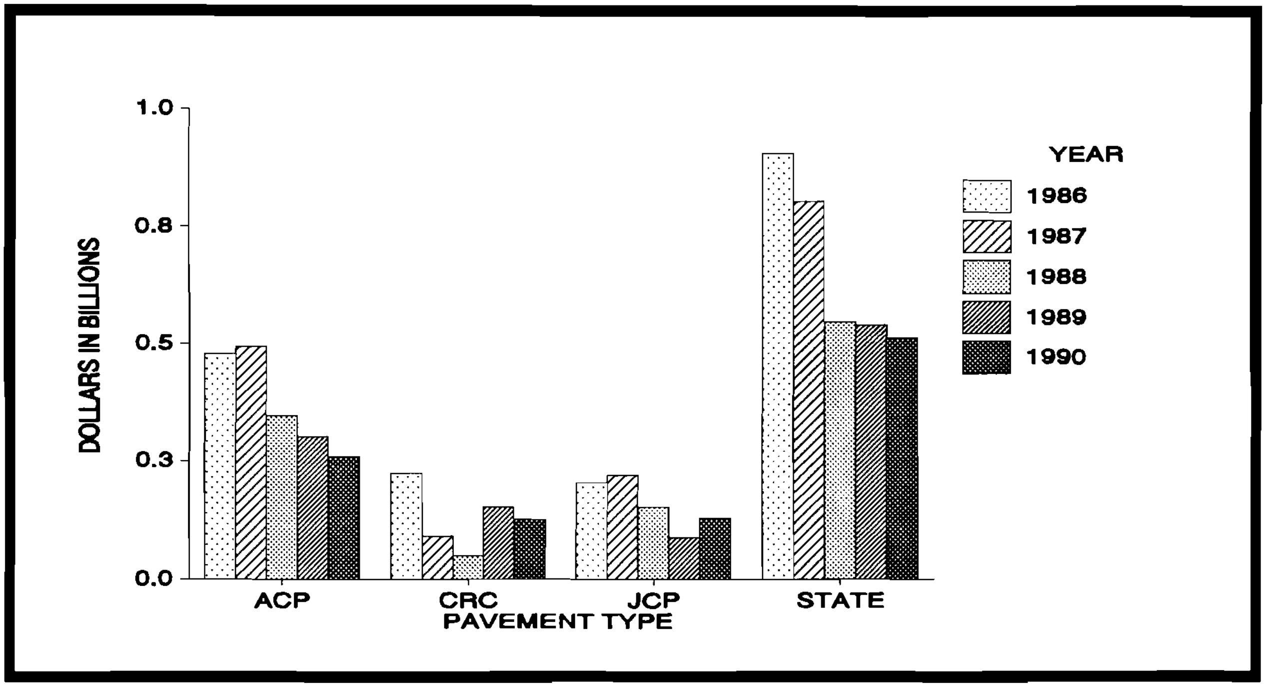


Figure 6.3 -- Estimated Funds Needed for Rehabilitation, by Pavement Type, 1986-1990.

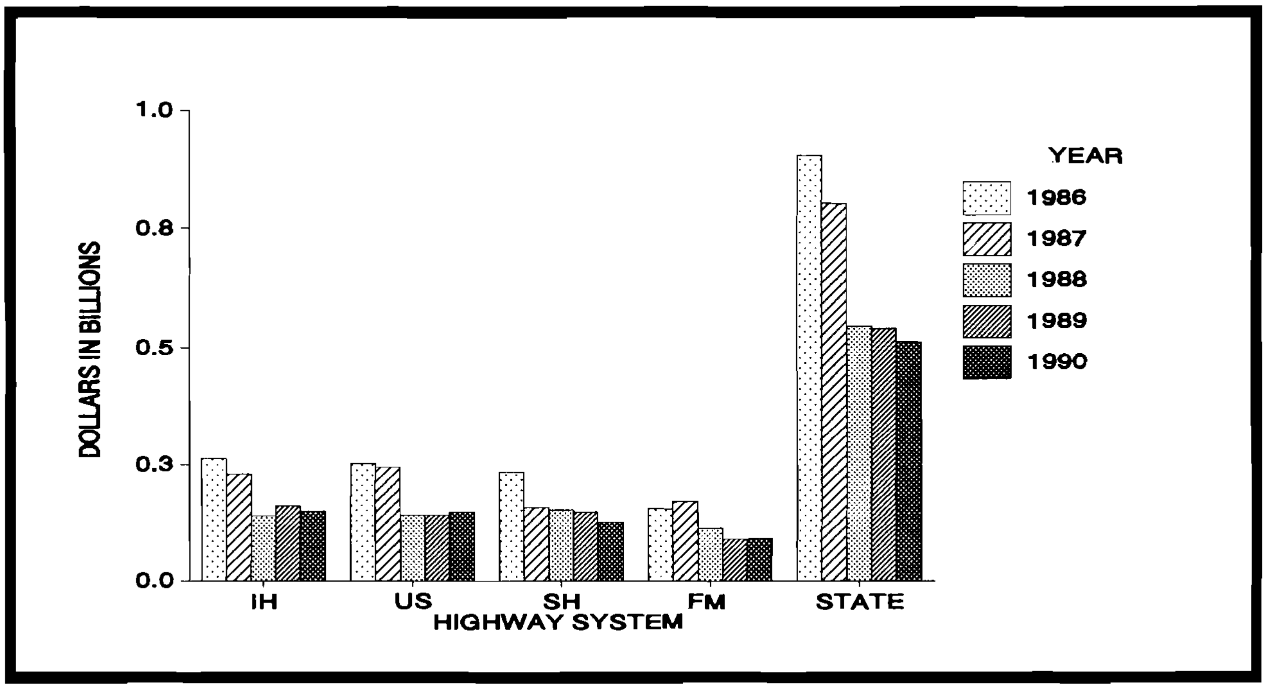


Figure 6.4 -- Estimated Funds Needed for Rehabilitation, by System, 1986-1990.

Summary of Statewide Pavement Rehabilitation Needs

In 1990, the overall rehabilitation needs decreased even though the overall condition got worse. The reason was less mileage in condition classes "C" and "D" fell into the rehabilitation needs category (PS < 35). Most of the 1990 condition was lost on low volume and low functional class roads on the US and SH systems. PS on these sections did not go below 35, because of low traffic and low functional class.

The amount of statewide mainlane mileage was less in 1990, which also attributed to the decrease in rehabilitation needs. This was due to PES conversion to the Texas Reference Marker (TRM) System. This problem should be solved, when all updates are made to the TRM road inventory files.

CHAPTER 7
ANALYSIS OF PAVEMENT DEFLECTION DATA

The previous chapters described the surface condition of Texas pavements, but that is not the whole story when it comes to effective pavement management. One must look beneath the surface to see the underlying conditions that play an important role in overall pavement performance. A general description of the relative stiffness of road materials can be obtained from geological land resource maps of Texas. For more specific information, the Department's Falling Weight Deflectometers (FWD) are used to analyze relative pavement strength.

Geological Characteristics and Subgrade Characteristics

Figure 7.1 shows the major land resource areas in Texas. Along the coast are the structurally weak soils of the Coast Prairie, Claypan Area, Blackland Prairies, and Rio Grande Plain. Comparing these areas with similar areas in Figure 7.2, which shows the modulus of elasticity (a measure of subgrade support), confirms the poor to very poor subgrade support (orange and red counties) that these soils provide. Large quantities of higher quality material must be imported into these areas to build strong roads. Even poorer subgrade support (red counties) is found along the Coast Marsh and Bottomlands, where providing strong paving materials and adequate drainage is extremely difficult or expensive.

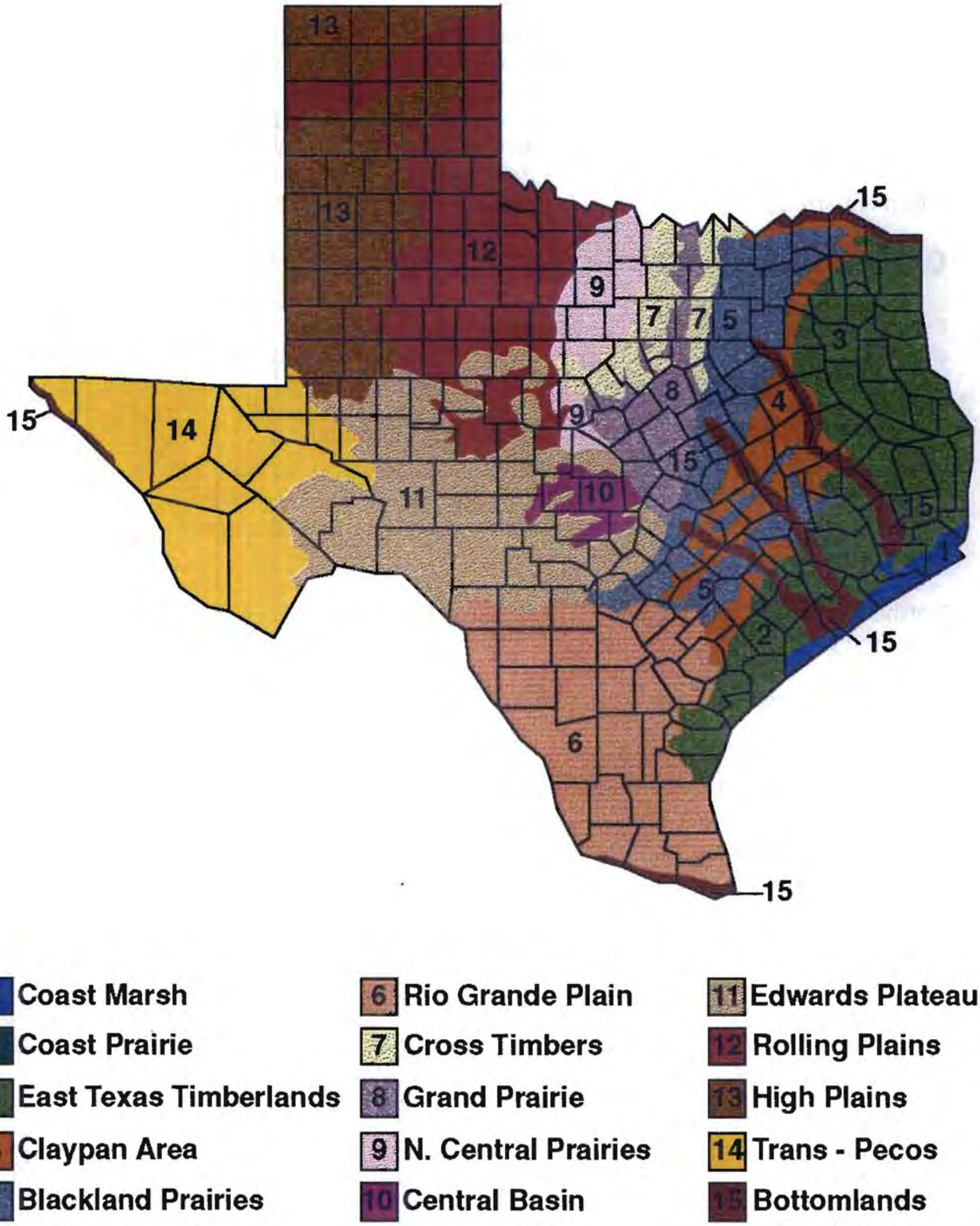
Northeast of the coastal areas is the East Texas Timberland where varying degrees of very poor (red counties) to good (green counties) subgrade support are found.

In the central portion of Texas, there is a sweeping arc of very stiff subgrade material, which includes the Cross Timbers, Grand Prairie, North Central Prairies, Central Basin, Edwards Plateau, and Trans-Pecos areas. While driving through these areas, one may notice many rock outcroppings, limestone formations, and other dense mineral deposits. These materials normally provide excellent foundations for long-lasting roads. If a weak area is encountered in this portion of the State, it is usually not far to mineral deposits, therefore strong material can be brought in and subgrade support maintained evenly. Most of the counties in this arc have average moduli values greater than 33,000 pounds per square inch, thus the roads require less imported materials, last longer, and need less maintenance, if traffic is similar, than other roads in the State.

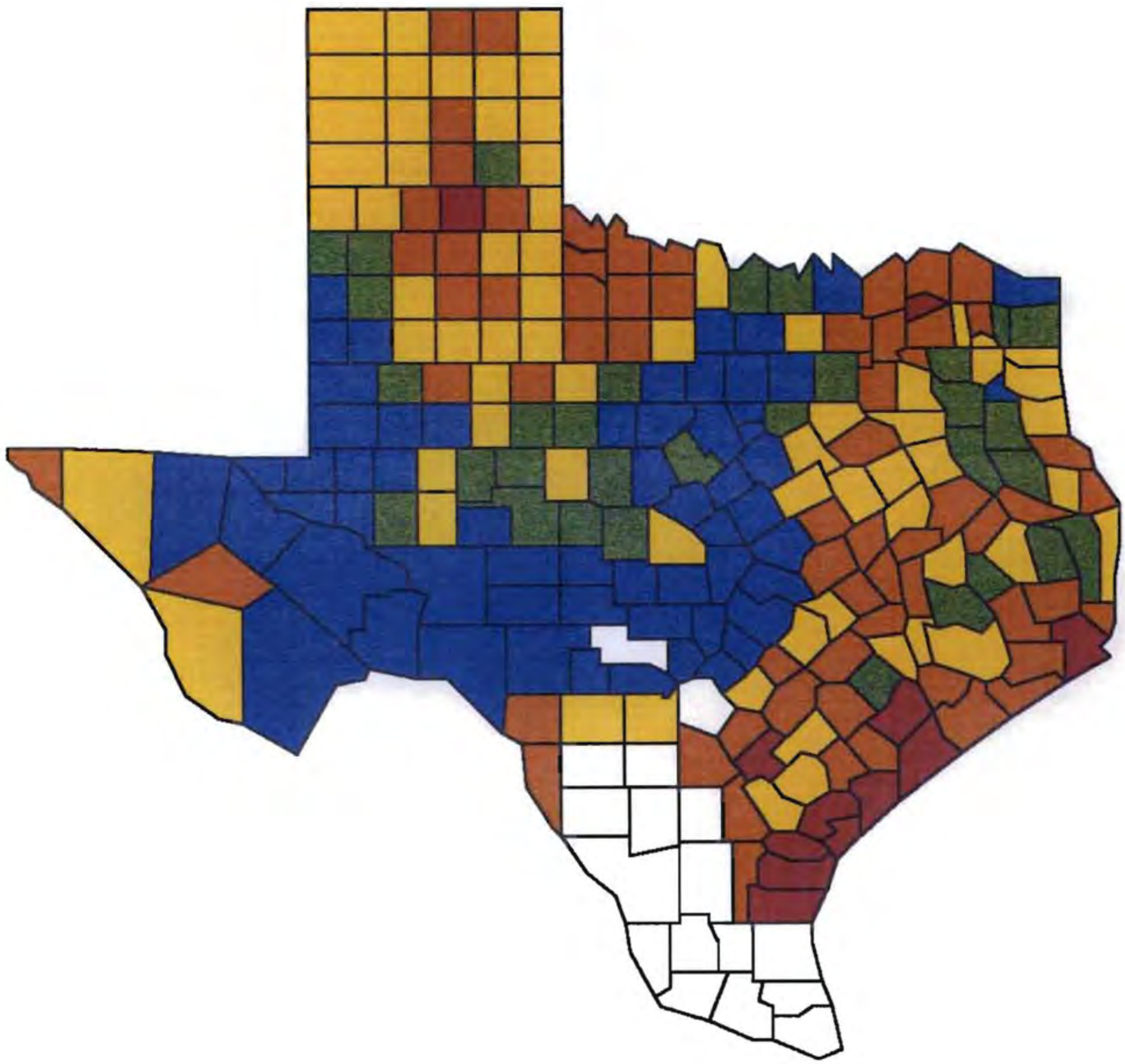
The northwest portion of the State is made up of the Rolling Plains and High Plains. Soil types in this area are similar to the clays and sands that make up the coastal areas. Most of the counties in this area exhibit low subgrade stiffness except for a few counties close to the rocky mineral deposits of the Edwards Plateau and Trans-Pecos areas.

Figure 7.3 contains subgrade support maps for 1987 through 1989, for historic comparison with the 1990 map (Figure 7.2).

LAND RESOURCE MAP



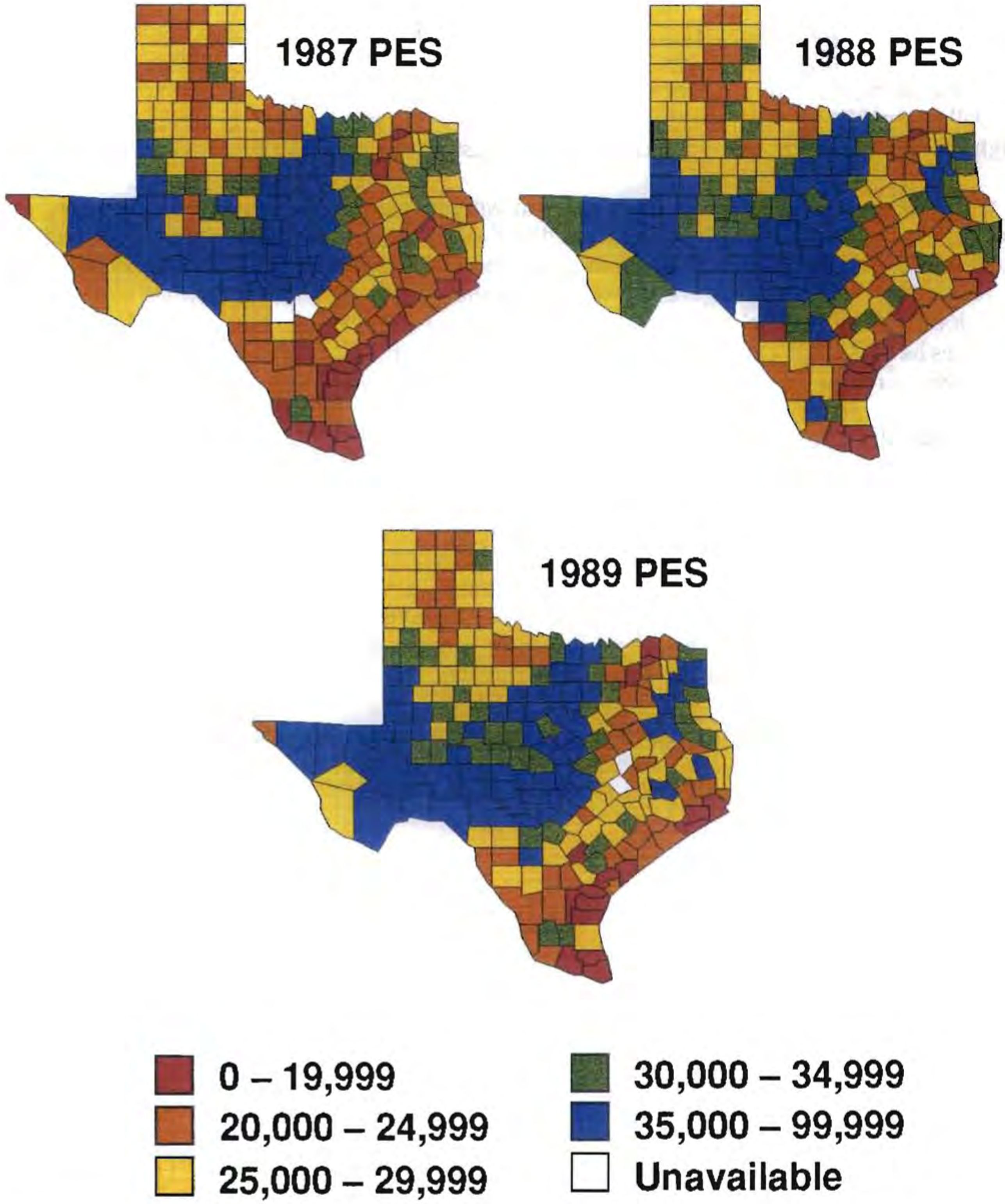
SUBGRADE SUPPORT
1990 PES — MAINLANE FWD SECTIONS



0 – 19,999
20,000 – 24,999
25,000 – 29,999
30,000 – 34,999
35,000 – 99,999
Unavailable

-Notes-

SUBGRADE SUPPORT
MAINLANE FWD SECTIONS



Surface Curvature Index and Pavement Condition

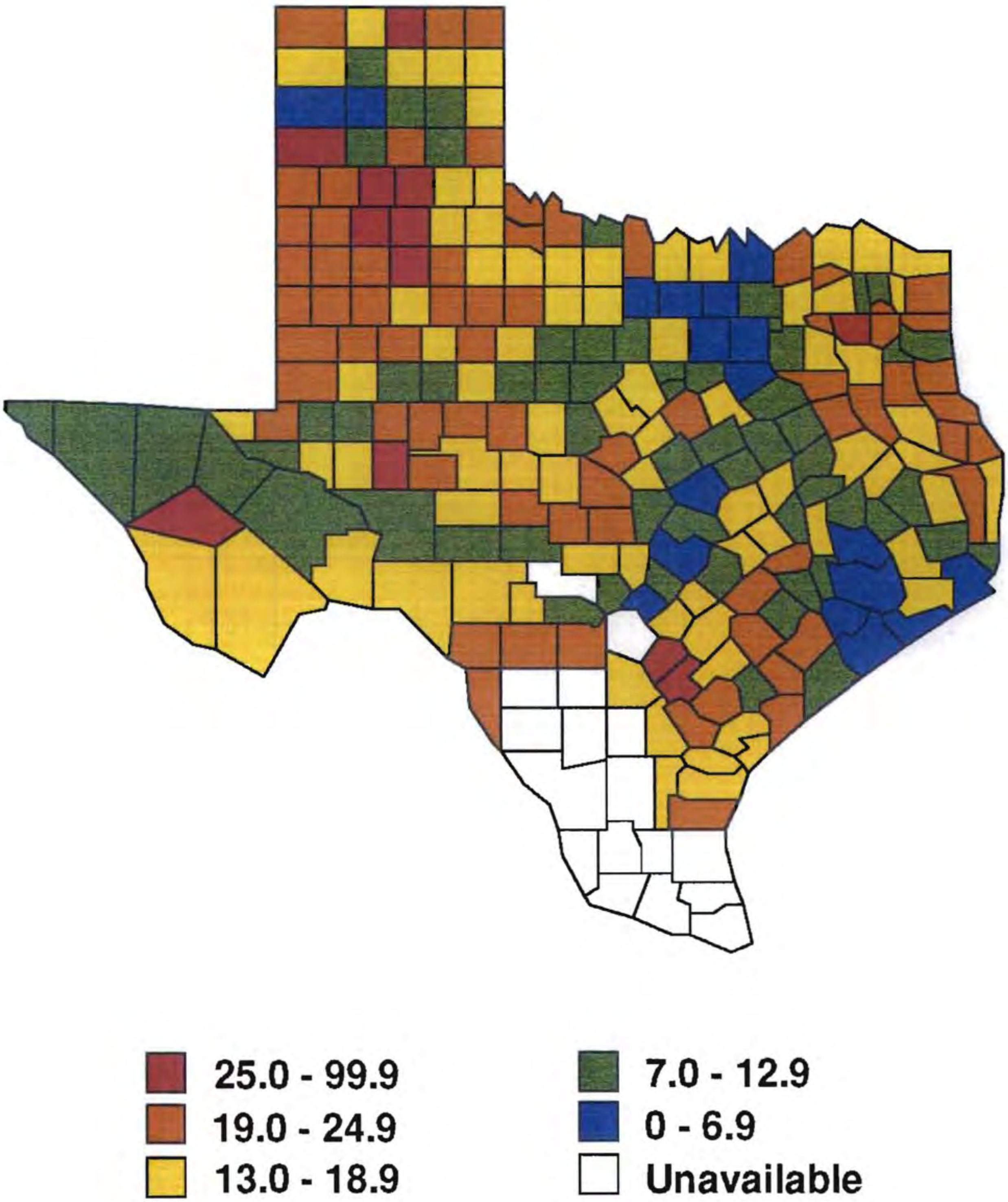
Pavement performance also depends on the stiffness of base and surface layers placed on top of the subgrade materials. Figure 7.4 shows the relative base and surface layer stiffness ("surface curvature index") of flexible pavements, by county. Blue counties indicate strong base/surface stiffness, while red counties indicate low base/surface stiffness. Note how high stiffness base/surface materials have bee used to compensate for weak subgrade areas along the coast. Concentrated areas of strong base/surface are also apparent along Interstate routes such as IH-10 (El-Paso to San Antonio), IH-20 (Odessa to Dallas), and IH-35 (Gainesville to Laredo). Many of the major urban counties also have high base/surface stiffness, primarily due to the use of thicker pavement layers.

It would be expected that pavement condition would closely track base/surface stiffness, but Figure 7.5, which depicts pavement condition (UPS) by county, suggests that pavement condition (at least surface condition, as measured by PES) is dependent on other factors as well. The legend in this figure was selected to show relative condition between counties and does not represent the UPS class tables introduced in Chapter 1. Almost all of the counties have average UPS in excess of 70 and therefore little comparison would be evident if the wider ranges of the UPS classification tables were used in the legend.

Green and blue counties depicting the extremely good pavement condition exist in many counties throughout the state, even in regions with poor subgrade support. The most striking example of good pavement condition in poor land resource areas is found near the coast where subgrade support and surface stiffness (SCI) is also fair, but pavement condition is maintained in the upper percentage of very good condition. Since pavement condition in this report is based on visual distress ratings, the appearance of good pavement condition in these areas can generally be maintained with the application of low cost seal coats. However, seal coats have little or no stiffness, and thus provide no resistance to rutting and other load-related distresses.

Figures 7.6 and 7.7 contain additional maps of surface curvature index and pavement condition, respectively, for 1987-1989.

SURFACE CURVATURE INDEX
1990 PES — MAINLANE FWD SECTIONS



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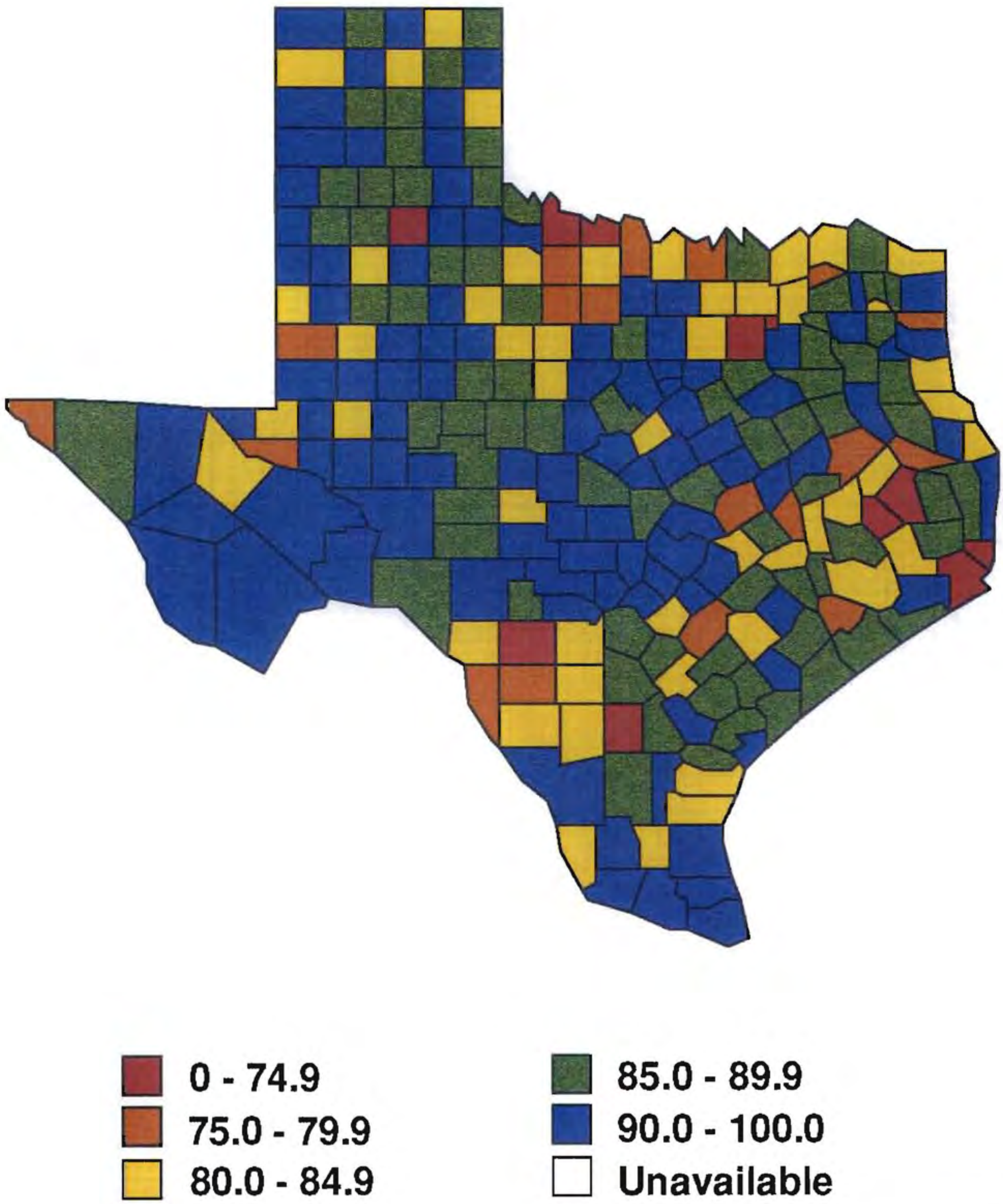
PAVEMENT CONDITION
1990 PES — MAINLANE ACP SECTIONS



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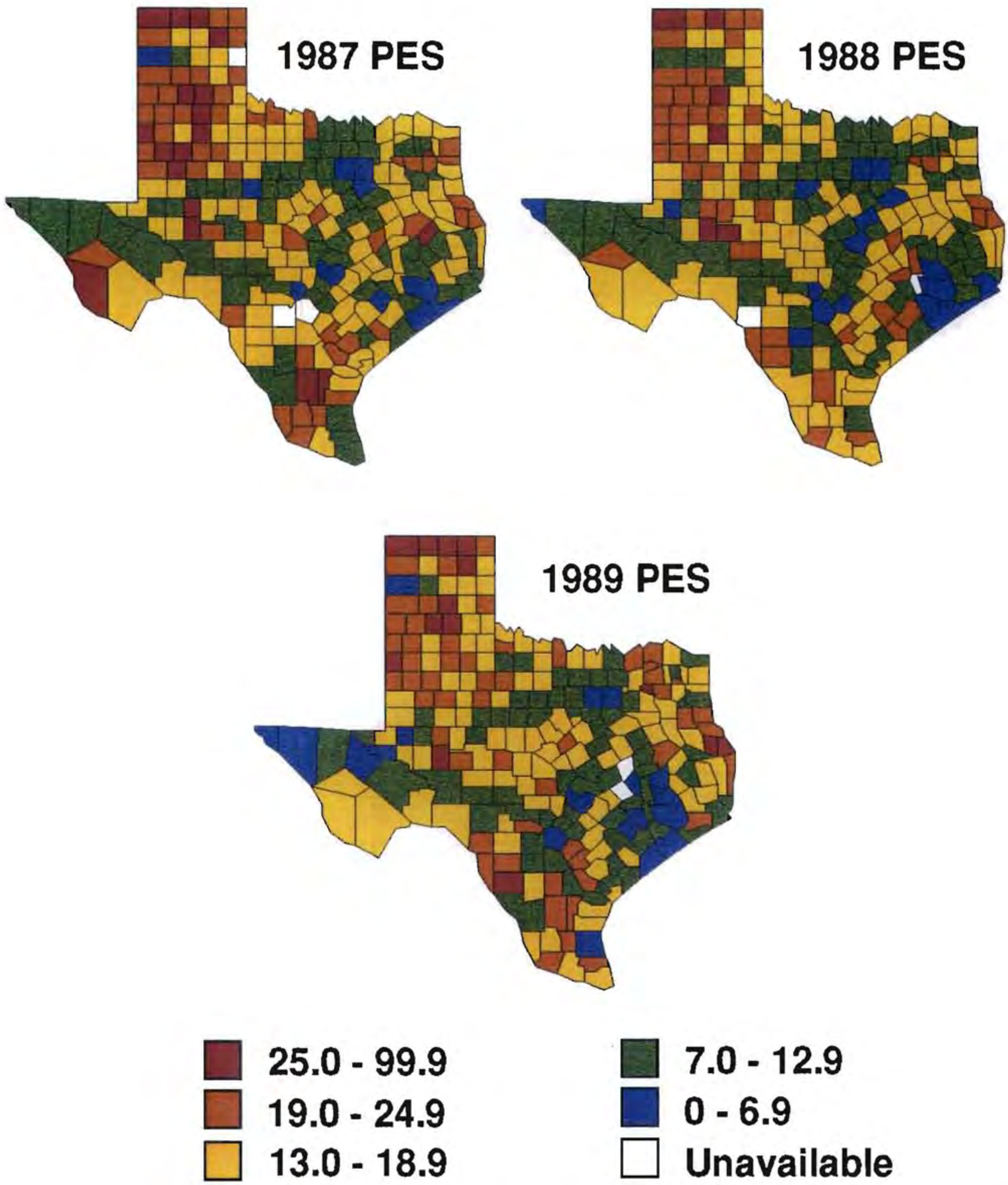
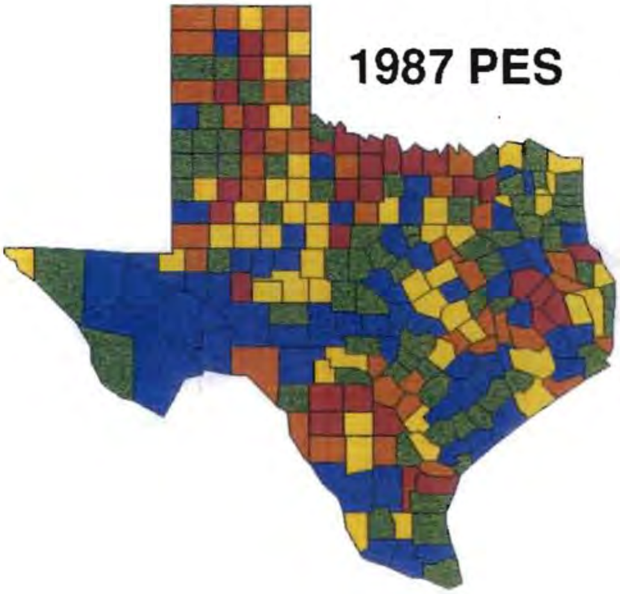
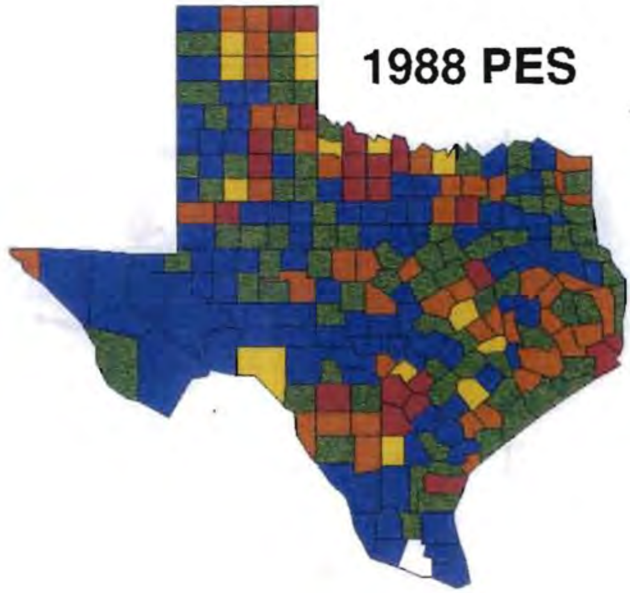
SURFACE CURVATURE INDEX
MAINLANE FWD SECTIONS

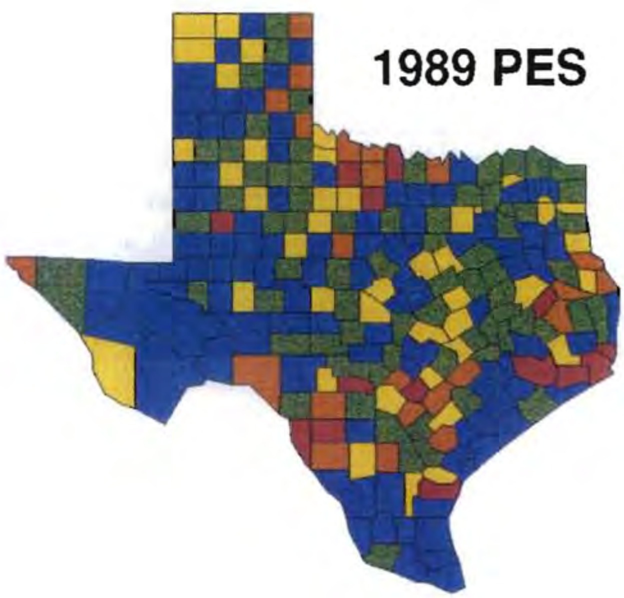


-Notes-

PAVEMENT CONDITION
MAINLANE ACP SECTIONS







- 0 - 74.9
- 75.0 - 79.9
- 80.0 - 84.9
- 85.0 - 89.9
- 90.0 - 100.0
- Unavailable

Falling Weight Deflectometer Measurements

This section will describe how the Falling Weight Deflectometer data can be used to measure relative pavement stiffness. Figure 7.8 illustrates how vertical compressive stresses due to a 9,000-11,000 pound FWD load spreads out through the various pavement layers.

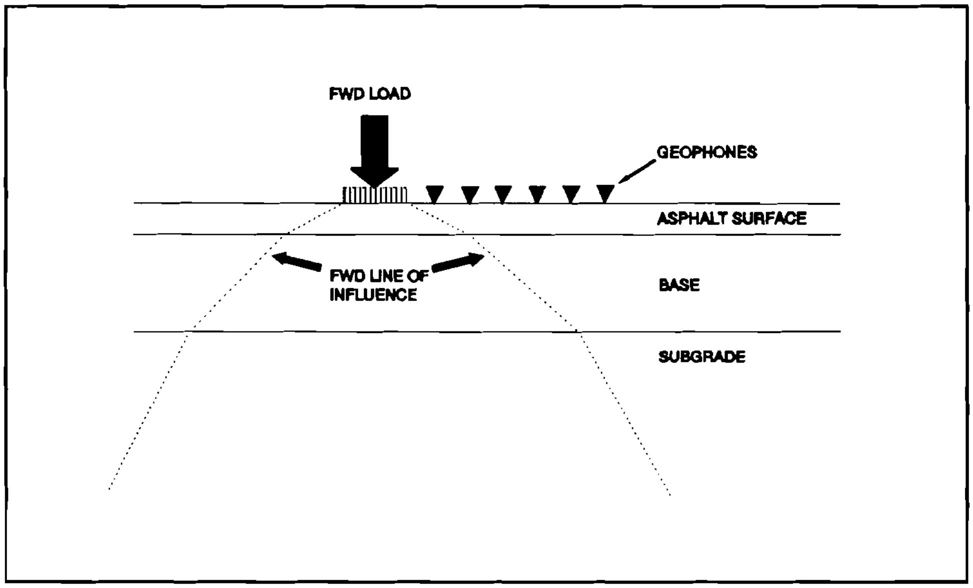


Figure 7.8 -- FWD Line of Influence.

The pavement deflects the most directly under the load. As the distance from the load increases, the line of influence spreads out through the layers of the pavement as represented by this conical zone, with the resulting deflection measured at the road surface being purely a result of the deformation within the conical stress zone. The result is a "bowl-shaped" basin on the pavement surface referred to as a "deflection basin". The FWD can only measure deflections along one bowl radius. A conceptual representation of an FWD deflection basin is shown in Figure 7.9.

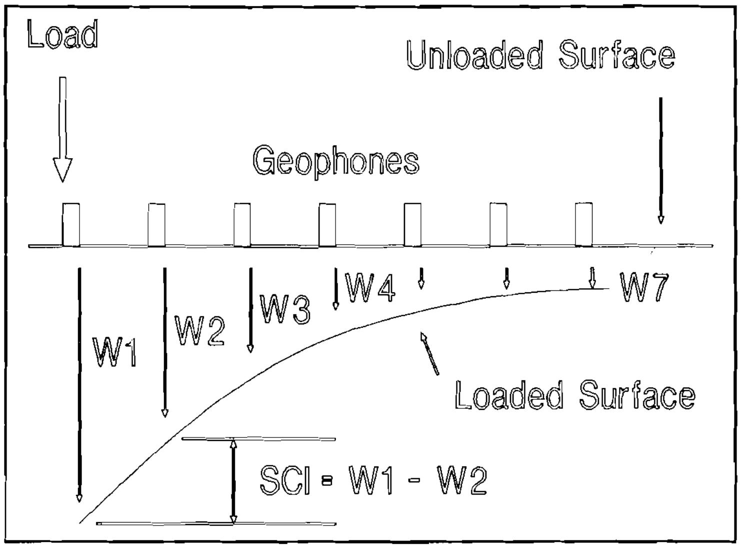


Figure 7.9 -- FWD Deflection Basin.

W1

The deflection measured at geophone one (W1), directly under the load, is a function of the combined deflection of all layers. The W1 sensor deflection can be used as an aid in identifying the weaker pavement sections within a highway segment. In general, if the W1 sensor deflection at a given test site exceeds the highway's average W1 sensor deflection plus one standard deviation, then we can characterize the pavement at that site as "weak" in comparison to the pavement in the rest of the highway.

SCI

The deflections measured at geophones one and two (W1) and (W2) are used to compute the Surface Curvature Index (SCI). SCI values are indicative of the stiffness of the base and surface layers. High SCI values mean that the base and surface layers are not performing their intended function of protecting the subgrade from excessive shear and compressive stresses. This may be an indication that the base and surface is not that thick.

W7

The deflection at geophone seven (W7), which is 72 inches from the load, is used as an indicator of subgrade stiffness. High values indicate that the subgrade is of poor structural quality or that it is saturated. Low values indicate a stiff subgrade and can be indicative of bedrock near the surface.

The 1989 PES Annual Report contains tabulated county statistics and more in-depth analysis of the above FWD reporting methods.

Structural Strength Index

PES uses a Structural Strength Index (SSI) to represent the combined effect of W1, SCI, and W7. The higher the values of W7 and SCI, the lower the SSI score. SSI is further adjusted downward for increasing amounts of rainfall and truck traffic. Thus for two pavements having similar deflections, the pavement with higher rainfall and truck traffic will have a lower SSI. PES does not incorporate SSI into pavement scores at this time. SSI values may be divided into three classes of pavement structural strength, as shown in Table 7.1:

TABLE 7.1 -- SSI Classes.

STRUCTURAL STRENGTH INDEX	CLASS
70-100	STRONG
40-69	MODERATE
1-39	WEAK

The 1990 PES structural survey indicated that 34.14 percent of the tested mainlane mileage had an SSI below 70, as indicated in Figure 7.10. These pavements which fall into the moderate and weak categories are considered "structurally inferior." Such "inferior" pavements may be in good to very good condition, but they can rapidly deteriorate unless frequently monitored.

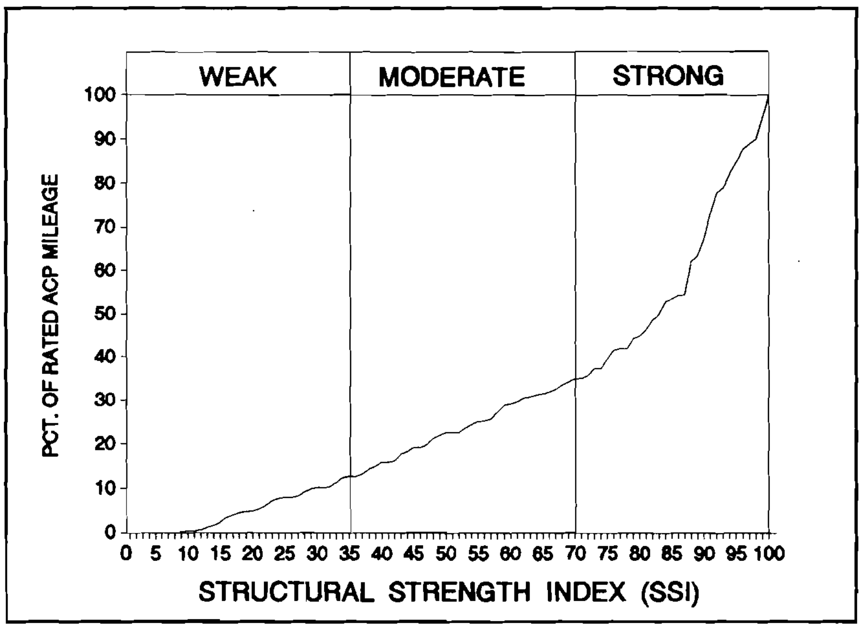


Figure 7.10 -- Statewide Distribution of Structural Strength Index Values 1990 PES.

Figures 7.11 through 7.15 indicate the SSI distribution for each pavement condition class in 1990. As illustrated in these figures, the good pavements are predominantly stronger than the poorer condition pavements, which tend to exhibit weaker structural strengths. This is expected, as the ability of a pavement to remain in good condition is directly influenced by its structural integrity. In 1990, the estimated ACP lane mileage was 156,955 miles, of which 100,742 miles were estimated to be in very good condition. However, 29.4 percent (29,651 miles) of these very good pavements were "structurally inferior" and classified as "moderate" or "weak" . This is an indication that we are covering up distresses with seal coats and thin overlays, and doing little to improve the structural strength of these pavements.

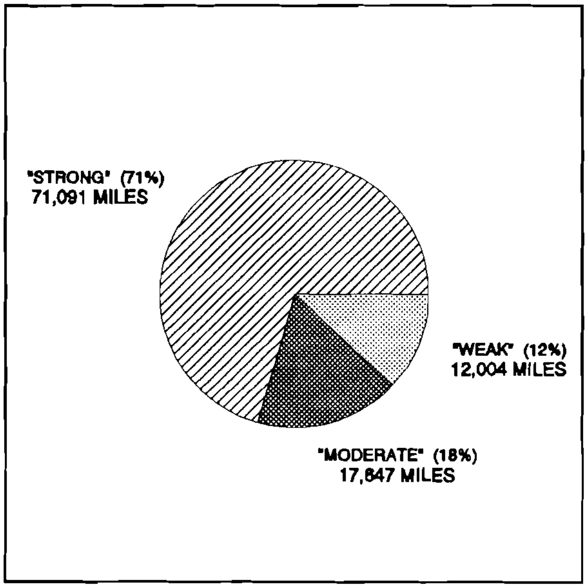


Figure 7.11 -- SSI Distribution for Condition Class "A" (Very Good) in 1990.

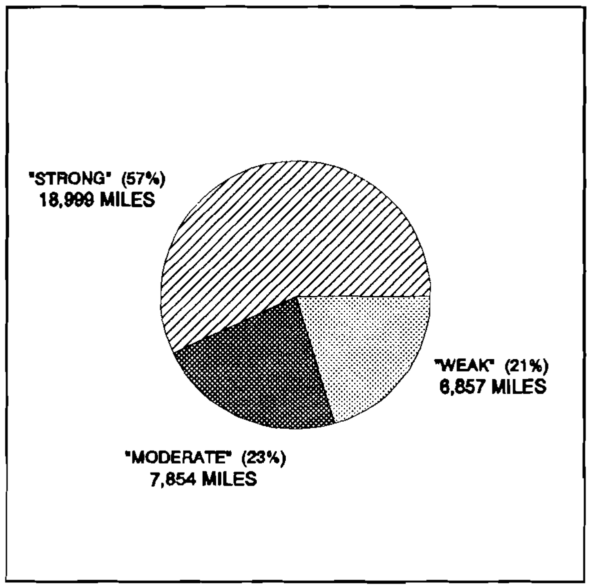


Figure 7.12 -- SSI Distribution for Condition Class "B" (Good) in 1990.

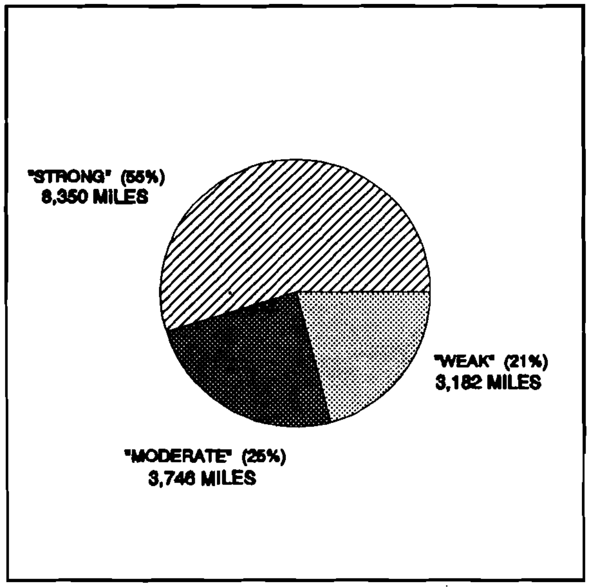


Figure 7.13 -- SSI Distribution for Condition Class "C" (Fair) in 1990.

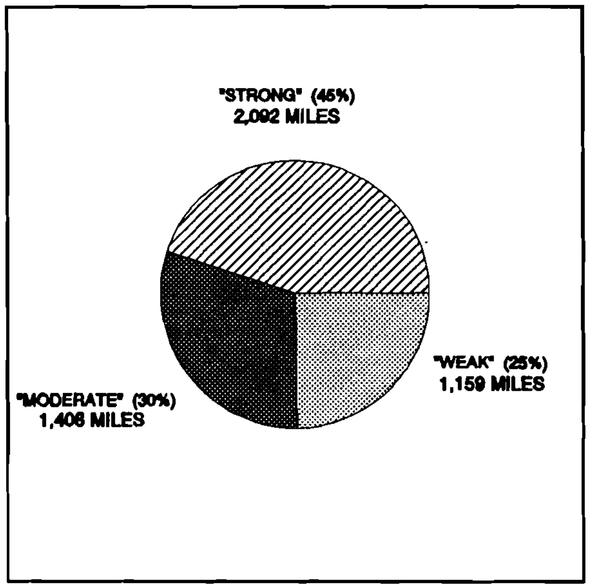


Figure 7.14 -- SSI Distribution for Condition Class "D" (Poor) in 1990.

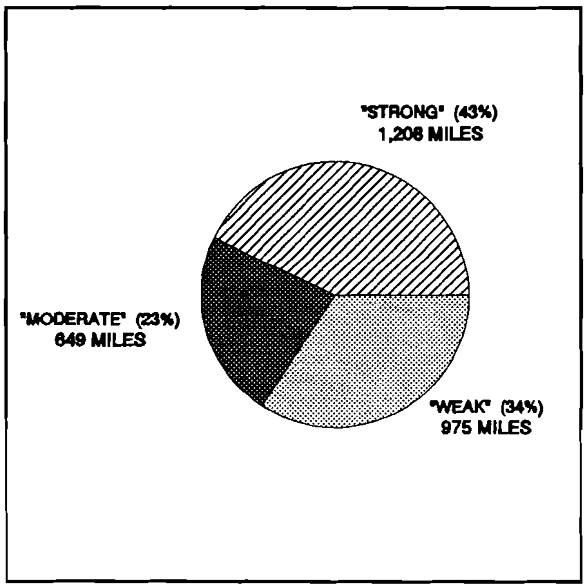


Figure 7.15 -- SSI Distribution for Condition Class "F" (Very Poor) in 1990.

Land Resources, Structural Strength, and Pavement Condition

In general, the surface condition of Texas pavements has been maintained in good to very good condition; however, over one-third of the ACP pavements have inferior structural strength. This is due to many widespread areas where naturally occurring material are less than optimal. Much engineering has gone into overcoming the limitations of these poor materials, but due to funding restraints, some areas of the State use less than adequate materials. Only through diligent maintenance efforts has pavement condition been preserved.

-Notes-

CHAPTER 8
GENERAL STATEWIDE RUTTING TRENDS

Rutting continues to be a major problem in some Texas counties. Approximately one-third of the mainlane PES flexible pavement sections have ruts ½" deep or greater over a length of 200 feet or more. The Western Association of State Highway and Transportation Officials (WASHTO) have suggested that any pavement with a rut depth of ½" or greater has reached the end of its design life, thus the PES rutting values represent a sizable problem.

General Causes of Rutting

Rutting on pavements has many possible causes. Rutting may be a result of inferior material properties due to inferior mix design procedures or construction practices. It may also be caused by improper pavement design. Often it is a result of increases in traffic volume or weights which were not addressed in the pavement design procedures. In areas where rutting has become a problem, either the design procedures need to be revised, or the weight of applied loads limited. Economics play an important role in pavement design, i.e. how strong a road is built and how much money can be put into rehabilitating a damaged road. Because of economics, a balance must be maintained between road design and applied loads. If this balance is changed, sometimes by a single excessive load, then road degradation can progress at an accelerated rate. The resulting rutting can become a costly distress to correct.

The physical appearance of rutting is a result of one or more of the following structural transformations. The surface layer may be relatively weak, allowing plastic flow of surface material from the wheelpaths. Or the base/subgrade is weak, allowing shoving of the base/subgrade material from the wheelpaths. Or the paving materials are experiencing permanent deformation, most notable in subgrade layers. In all cases, the wheelpaths become depressed in relation to the surrounding pavement surface and ponding will occur in these depressions during wet weather. This water ponding greatly increases the potential for hydroplaning, where the tires of vehicles separate from contact with the road. Thus rutting poses a safety problem, as well as a structural problem, to Texas pavements.

Tensile stresses in the pavement can also cause cracks which propagate to the surface. Once these cracks reach the surface, water can infiltrate the base and subgrade causing additional loss of pavement stiffness. Water ponding in wheel ruts intensifies the problem by retaining water over cracks and allowing more time for infiltration.

Minimizing rutting generally involves major road reconstruction whereby the deficient layer must be removed and replaced. Treating the surface layers of a road only covers up the underlying problems and offers no long term solution. Since it is not economically feasible to rehabilitate all rutted roads throughout Texas, a prioritization method should be followed such the areas in most need of reconditioning are given a high priority. This will ensure uniform levels of safety, regardless of location.

Rutting Distributions on ACP Sections

Figure 8.1 shows the average percentage of rutting by county for all 1990 PES ACP sections. Blue counties indicate little or no detectable rutting while red counties indicate that greater than 50% of the PES sections were rutted in excess of ½".

Note that Figure 8.1 shows negligible rutting in the western portion of the State. Pavements in these western counties resist rutting, because they are in an area of little moisture, strong materials, and lower ADT. Blue counties are also evident around Houston, Dallas, and Fort Worth, where heavy congestion and large amounts of truck traffic justifies higher strength materials and stronger designs.

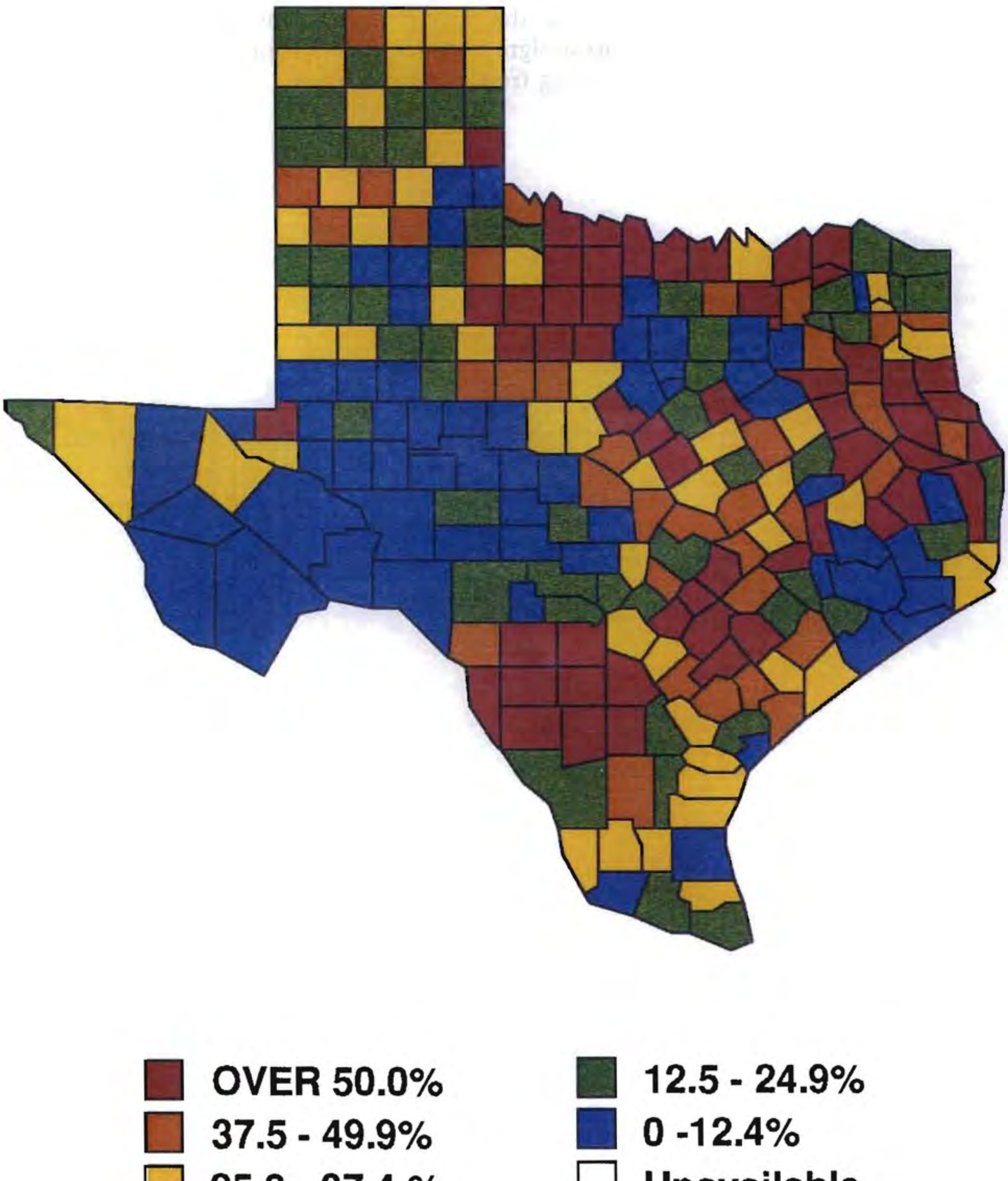
The southern portion of the state has some heavily rutted counties (red) where hard freezes in 1983 and 1989 cracked pavement surfaces. These cracks allowed water to flow beneath the pavement surface and weaken the base and subgrade layers. Surface treatments can be used to prevent further saturation, but they do not strengthen the pavement structure. Major rehabilitation is needed on these sections to restore structural strength.

There are two other areas in the State where rutting problems have persisted: East Texas and North Central Texas.

The high percentages of rutting found in East Texas can be attributed to sandy clays, high rainfall, poor drainage, and heavy truck traffic. All of these factors combine to shorten pavement life. Truck traffic is promoted by good agricultural conditions and other naturally occurring resources.

The high percentages of rutting found in the North Central Texas appears to be a mixture related problems. The composite pavements are exhibiting abnormal amounts of rutting, which is an unusual occurrence for these pavements. Some rutting can be attributed to weak subgrade stiffness, poor material sources, moderate rainfall, and heavy truck traffic, but not to the extent present in East Texas. Adjacent counties immediately to the west of this area are also in the same land resource area and similar rainfall, but these counties have maintained a good resistance to rutting. This indicates that the asphalt mix designs in the highly-rutted counties allow too much plastic flow of the surface layers. The rigid concrete sub-layer in the composite pavements aggravates the problem because it does not flex as much under load as the asphalt surface does.

RUTTING ON TEXAS HIGHWAYS
1990 PES — MAINLANE ACP SECTIONS



Rutting in Previous Years

Figure 8.2 shows the average percentage of rutting by county for 1987 through 1989.

Percentages of rutting have not changed dramatically except in the southern portions of the State.

As noted before, rutting in certain areas of the State continues unchecked. A thorough review of pavement design criteria, mix design, material specifications, funding, and load restrictions are required to alter the rutting trends in these areas.

Rutting Distributions on Specific Pavements

Figure 8.3 shows the distribution of rutting on four types of asphalt pavements: *SURFACE TREATED, THIN ASPHALT, THICK ASPHALT* and *COMPOSITE* sections.

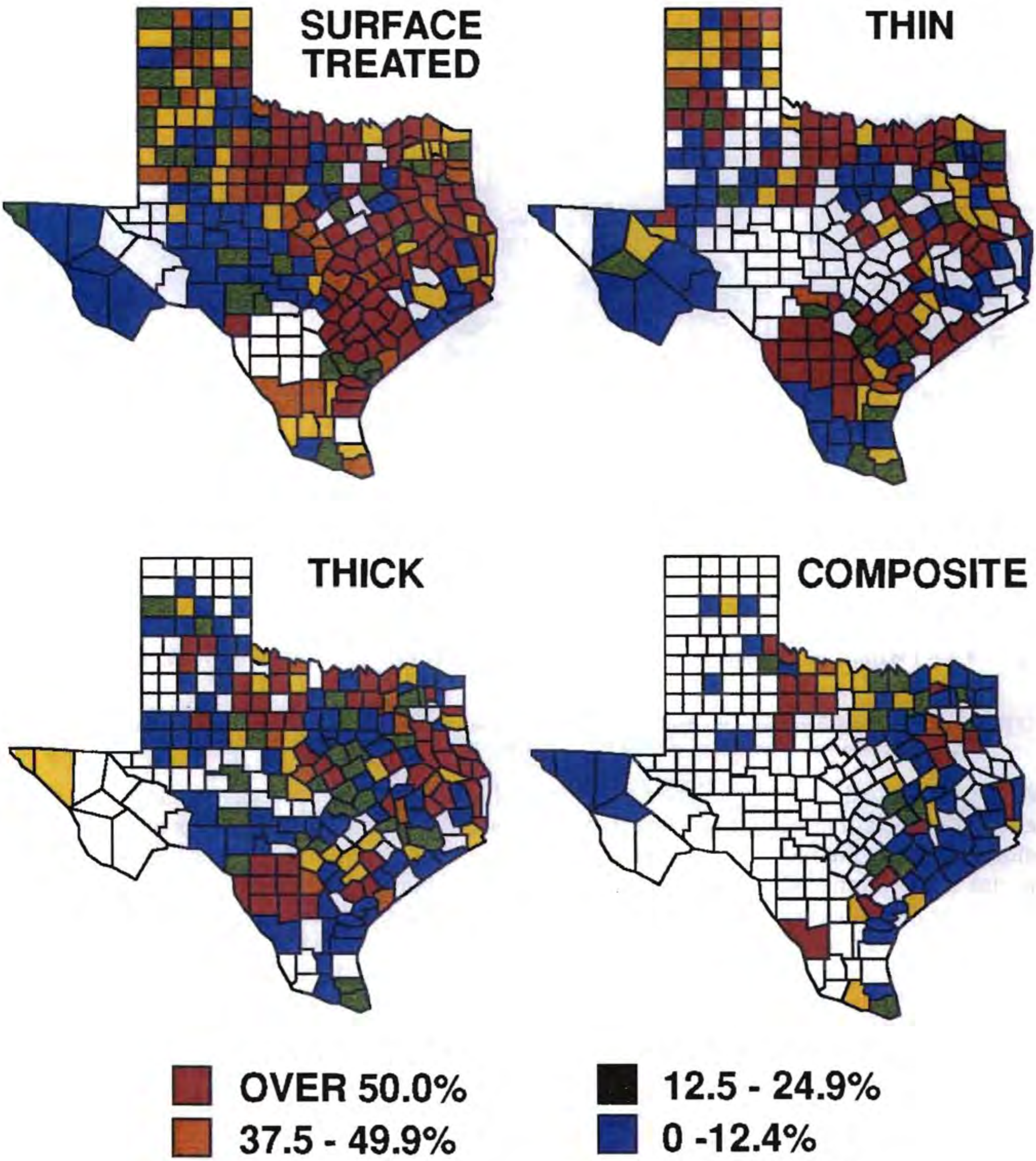
SURFACE TREATED pavements are typical of those found on the Farm to Market system. Economics and low traffic volumes restrict the money invested in such roads. Thus low-cost asphaltic surface treatments are applied to base materials. The surface treatment controls dust and erosion problems, but provide no structural support. Thus the base and subgrade are subjected to full wheel loads. These roads are very susceptible to damage by loading and therefore load limits based on engineering evaluations are sometimes used to protect them. Note: heavy rutting is found in the eastern portion of the State, where the heavy traffic loads and poor subgrade materials combine to shorten the life of these pavements.

THIN ASPHALT pavements are used where additional pavement structure is needed to reduce maintenance needs, but cost is a constraining factor. Since the asphalt thickness of these sections is typically less than two and a half inches, the asphalt surface provides a small portion of the pavement's overall structural strength. Heavy loads on these pavements can easily cause rutting unless the base material is exceptionally strong, such as in West Texas.

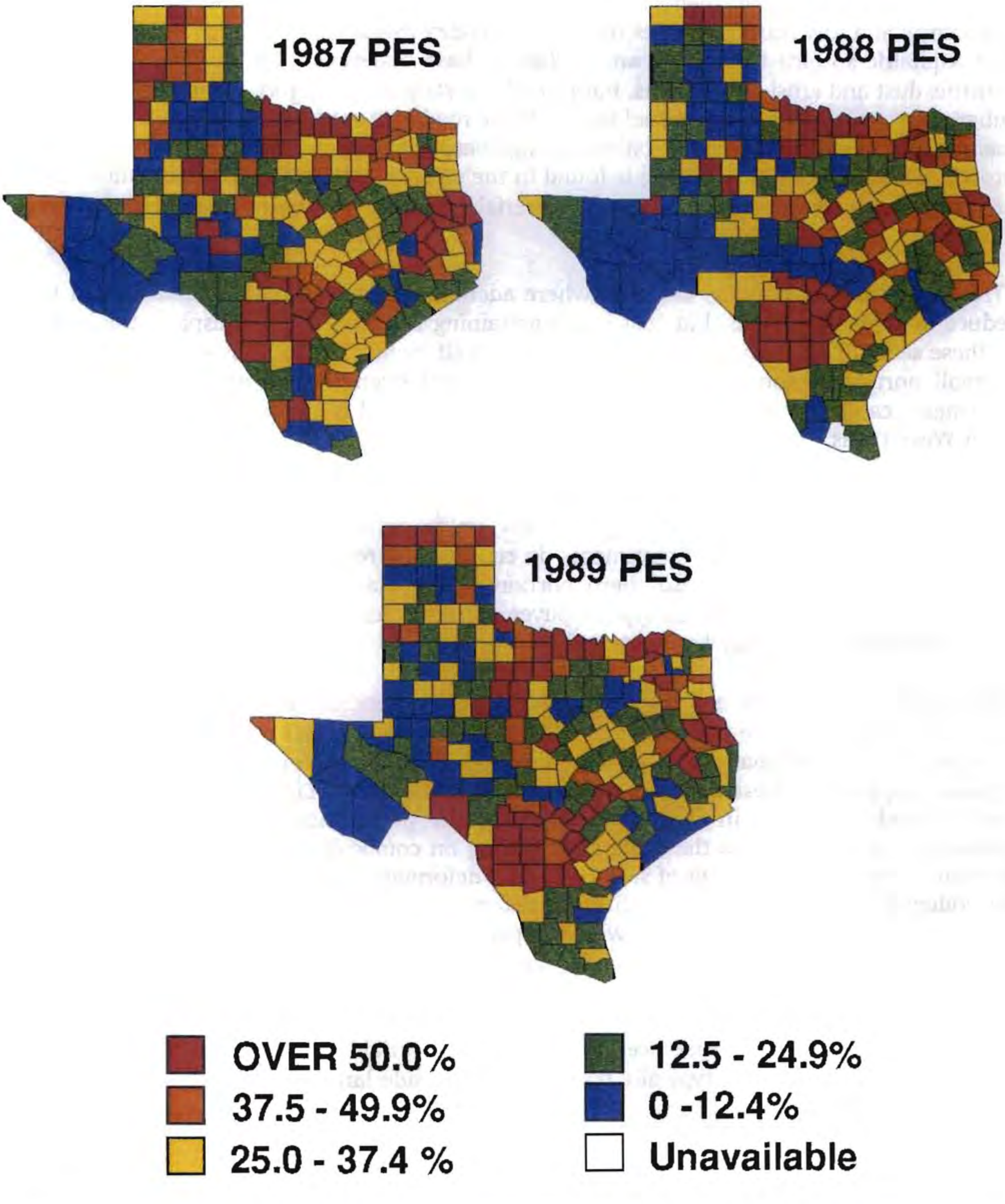
THICK ASPHALT pavements are used where heavy load bearing capacity is needed. Rutting should be minimal on these pavements, unless applied loads substantially exceed design criteria. Most of these pavements do reflect good resistance to rutting (blue and green areas), except for the southern portion of the State where freeze damage has occurred. Heavy rutting on this type of pavement indicates that a review of traffic loads and pavement designs may be warranted.

COMPOSITE pavements are those on which asphalt concrete have been overlaid on portland cement concrete pavements. Note the high success of this method in the coastal areas where concrete material is used as a base to compensate for weak subgrade. The asphalt is applied to these pavements to maintain ride quality. Due to the excellent base and subgrade materials in central Texas, composite pavements are not needed. PES indicates a few counties in the State have rutting on composite sections in excess of 50 percent. This is either a result of surface asphalt deformation or compressive deformation on widened concrete pavements. Surface deformations on composite pavements are a result of inadequate mix designs which experience plastic flow under loading. The inadequacies of these mix designs can be due to round aggregates or unstable mixtures. In many widened concrete pavements, asphalt pavement designs are applied to structurally weaker shoulders and then striped as travel lanes. These overlaid shoulders rut because they are not as strong as the overlaid concrete. Overlaid shoulders are troublesome because heavy truck traffic typically travels in the outside lane.

RUTTING ON TEXAS HIGHWAYS
MAINLANE ACP SECTIONS



RUTTING ON TEXAS HIGHWAYS
MAINLANE ACP SECTIONS



Severity of Rutting

Figure 8.4 shows that the number of sections containing any amount of rutting greater than ½" deep continues to fluctuate around 30 percent.

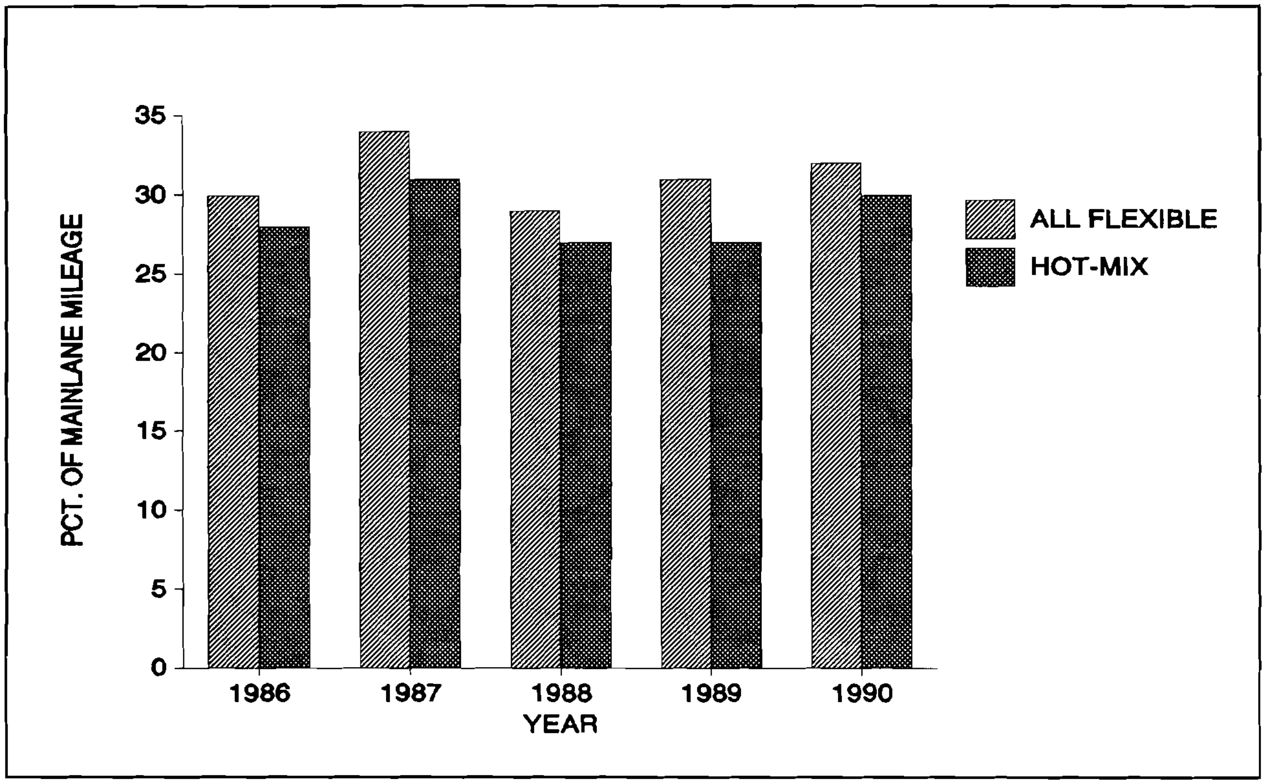


Figure 8.4 -- Flexible Vs. Hot-Mix PES Sections, Rutting on Texas Highways 1983-1989.

NOTE: Comparisons of percentages in this figure are slightly different from percentages reported in last year's report because of conversion to the Texas Reference Marker system.

While not all roads can be designed to withstand loading, some corrective measures can be taken in certain areas of the State that have localized rutting problems. As mentioned before, rutting is the result of loads applied to the pavement surface that exceed the design. Special studies done while tracking the movement of permitted loads show that even a single passage of a very heavy load can immediately cause pavement damage. One way of expressing pavement wear is to use terminology from the 1986 American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures. The term "Equivalent Single Axle Loads," or ESALs, represents the effect of any vehicle load and axle configuration into an equivalent number of applications of a *STANDARD* 18,000 pound (18-kip) axle load. Since rutting is a direct result of axle load applications, it is of interest to evaluate some example comparisons of ESAL loads.

Table 7.1 shows equivalent 18-kip ESAL factors for various single axle loads from 2,000-50,000 pounds.

Table 7.1 -- Axle Load Equivalency Factors For Flexible Pavements. [1]

Single Axle Load (kips)	Pavement Structural Number (SN)					
	1	2	3	4	5	6
2	.0002	.0002	.0002	.0002	.0002	.0002
4	.002	.003	.002	.002	.002	.002
6	.009	.012	.011	.010	.009	.009
8	.030	.035	.036	.033	.031	.029
10	.075	.085	.090	.085	.079	.076
12	.165	.177	.189	.183	.174	.168
14	.325	.338	.354	.350	.338	.331
16	.589	.598	.613	.612	.603	.596
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.59	1.56	1.55	1.57	1.59
22	2.49	2.44	2.35	2.31	2.35	2.41
24	3.71	3.62	3.43	3.33	3.40	3.51
26	5.36	5.21	4.88	4.68	4.77	4.96
28	7.54	7.31	6.78	6.42	6.52	6.83
30	10.4	10.0	9.20	8.60	8.70	9.20
32	14.0	13.5	12.4	11.5	11.5	12.1
34	18.5	17.9	16.3	15.0	14.9	15.6
36	24.2	23.3	21.2	19.3	19.0	19.9
38	31.1	29.9	27.1	24.6	24.0	25.1
40	39.6	38.0	34.3	30.9	30.0	31.2
42	49.7	47.7	43.0	38.6	37.2	38.5
44	61.8	59.3	53.4	47.6	45.7	47.1
46	76.1	73.0	65.6	58.3	55.7	57.0
48	92.9	89.1	80.0	70.9	67.3	68.6
50	113.	108.	97.0	86.0	81.0	82.0

This table is used to convert single axles loads only. Different tables must be used for closely spaced axles sets, such as the tandems and tridems. Comparison of different structural numbers indicate that the structural number has negligible effect on the number of ESALs compared with the effect of axle loading. For simplicity, an average structural number of three is used in the following examples.

[1] Source: "1986 AASHTO Guide for Design of Pavement Structures," Appendix D.

18-kip ESAL Examples

A truck is loaded to 10,000 pounds on the steering axle and 20,000 pounds on the rear axle. Table 7.1 shows .090 + 1.56 ESALs representing the truck's wear on a road. The total in this case 1.65 ESALs or 1.65 passes of a standard 18,000 pound single axle.

For a heavy car with 2,000 pounds on the steering axle and 2,000 pounds on the rear axle, the pavement loading on the road is .0004 ESALs.

Therefore it would take 4125 passages of a 4,000 pound car to equal to one passage of the 30,000 pound example truck. If comparisons were done with weights typical of today's lighter cars, then the number of equivalent car passages would be much greater.

To illustrate the effect of extremely overweight vehicles (whether permitted or not), an example with axle weights double the truck used in the previous example is used. Adding 1.56 + 34.3 together gives 35.89 ESALs. This is 21.75 times as much wear as the 30,000 pound truck and equates to 89,725 passages of the 4,000 pound car. Fortunately, the number of extremely overweight vehicles is limited, but when they do travel on a given road, the number of ESALs they use reduces the remaining life of that road.

Accuracy of Rutting Measurements

Audits of PES distress rating data indicate rutting is one of the more difficult distresses to rate consistently. Even when asked to rate rutting into three categories (<½", ½" to 1", and >1" deep), independent rating teams typically agreed only about 72 percent of the time and was primarily on sections with little or no rutting.

TABLE 7.2 -- Percent Agreement on Types of Rutting.

RUT CLASS	PERCENT AGREEMENT			
	1987	1988	1989	1990
<½	79.79	81.92	85.65	82.91
½" to 1"	39.20	41.94	45.22	48.61
>1"	27.77	31.58	17.39	14.81
ALL	65.61	72.51	72.71	72.30

NOTES: Ruts 3" or deeper are measured along their length and rated as failures. Failures in excess of 40 feet are rated as multiple failures determined by dividing the total failure length by 40.

D-18PM plans to automate rut depth measurements. These automated methods will provide more objective rut measurements.

Pavement Design, Loading, and Resultant Pavement Distresses

The preceding maps show how rutting distresses are concentrated in particular areas throughout the State and how some of the stronger pavement types are experiencing high percentages of rutting. When water begins to pool within these ruts, hydroplaning becomes a dangerous safety consideration. Hydroplaning can occur at any speed depending on tire pressure, wheel load, etc. Even if a vehicle slows below speeds characteristic of hydroplaning, driving instabilities can still occur when displacing pooled water. Since rutting is the result of heavy axle loads, it is recommended that design and enforcement techniques be improved in heavily-rutted counties.

Special studies tracking movement of permitted overloads show that some loads have the potential to cause immediate visual distresses, particularly where water has weakened the base and subgrade. Adjusting load limits in conjunction with seasonal structural stiffness changes, where feasible has the potential to improve road life characteristics. The FWD is an excellent source for determining the extent of seasonal structural strength changes.

Review of adequate compensation to counties easily susceptible to rutting from overloads is recommended along with scaled fees based on equivalent ESALs as described in AASHTO guidelines. Currently permit fees can at times be negligible in comparison with the amount of damage caused. Rutting in Texas is a highly visible distress and can only be brought under control through the use of more equitable load versus wear techniques, whereby the areas in need of funding are compensated adequately. Given the standardization of paving techniques in Texas, it is highly unlikely that rutting in the heavily damaged counties can be attributed to design inadequacies alone.

-Notes-

CHAPTER 9
CONSTRUCTION AND MAINTENANCE FUNDING

An important factor in constructing and maintaining a highway network is sufficient funding. The Texas highway network reached its highest condition level in 1989, as indicated in Figure 9.1. This condition level was achieved with fuel tax increases in 1985 and 1987. This chapter will examine the maintenance and construction funding from fiscal year (FY) 84 to FY 91. A fiscal year in the Department is from September 1 of one year to August 31 of the following year (e.g., FY84 is September 1, 1983 - August 31, 1984).

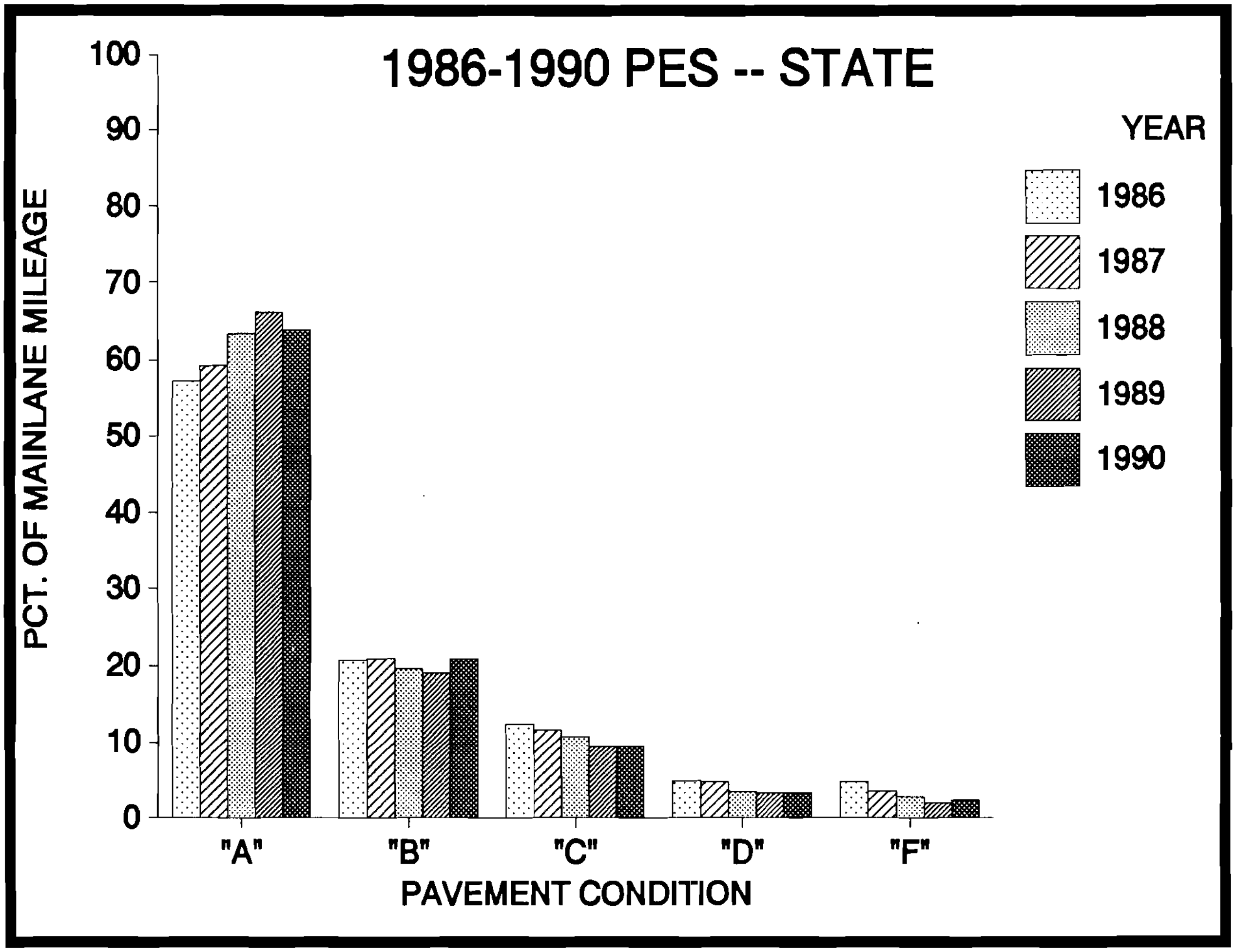


Figure 9.1 -- Condition of the Texas Highway Network, 1986-1990.

Construction Expenditures

FY91's (1990 PES data) construction expenditures before inflation were $1,798,575,840. Considering inflation, the expenditures in FY84's dollars drop to $1,234,902,172. FY84 is used as a basis because PES data collection began in FY84. FY84 "Constant" dollar amount is well below the 1986 level, after the first tax increase. The FY84 "Constant" dollars were calculated using the Kiplinger Consumer Price Index. The amount of inflation between FY84 and FY91 was 31.34 percent. Without inflation, construction funds have dropped from $2,064,975,855 in FY88. Since most construction projects take two years to complete, the slight decrease in overall condition of the Texas highway network in 1990 is the first sign of reduced spending in FY89.

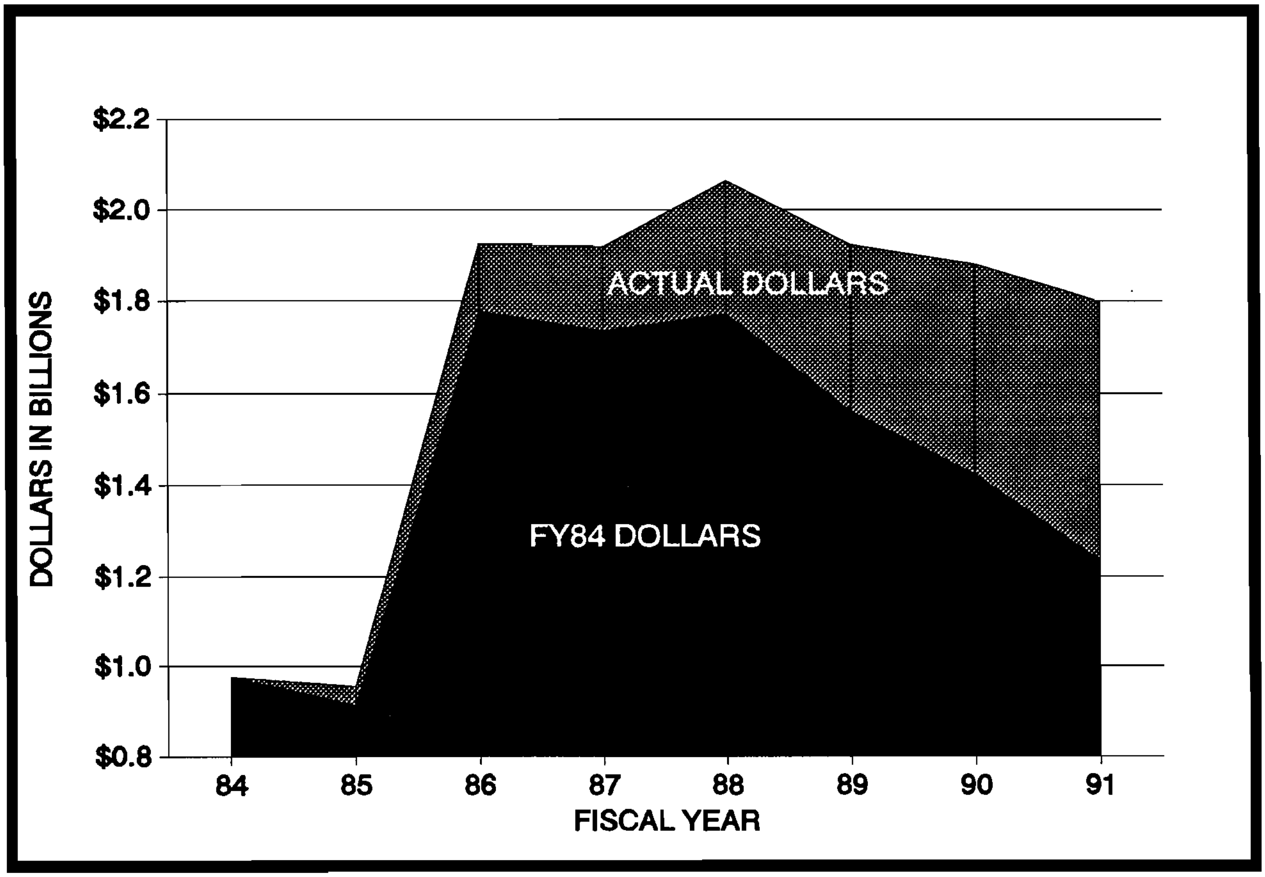


Figure 9.2 -- Construction Expenditures in Actual and FY84 Dollars, FY84-FY91.

Maintenance Expenditures

Maintenance expenditures in FY91 were $567,962,664, down from FY90's eight year high of $597,159,664. When inflation is considered, the maintenance expenditures dropped below the FY86 level for the first time. This along with a constant dollar reduction since FY88, is a major contributor to the overall drop in condition in 1990. The decrease in maintenance expenditures is most evident in the individual ACP distresses, where for the first time in the last five years, all cracking distresses increased. Figure 9.3 shows the maintenance expenditures from FY84-FY91 in "Actual" and "Constant" dollars.

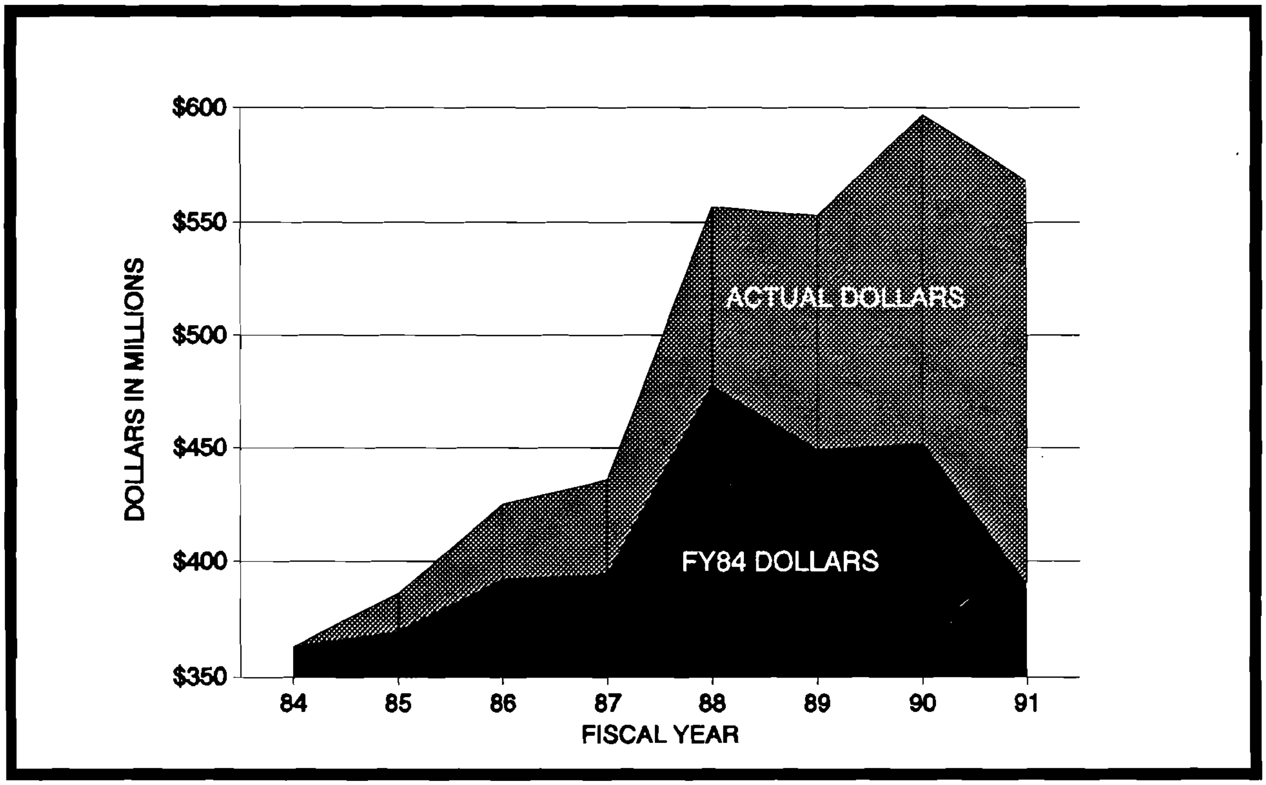


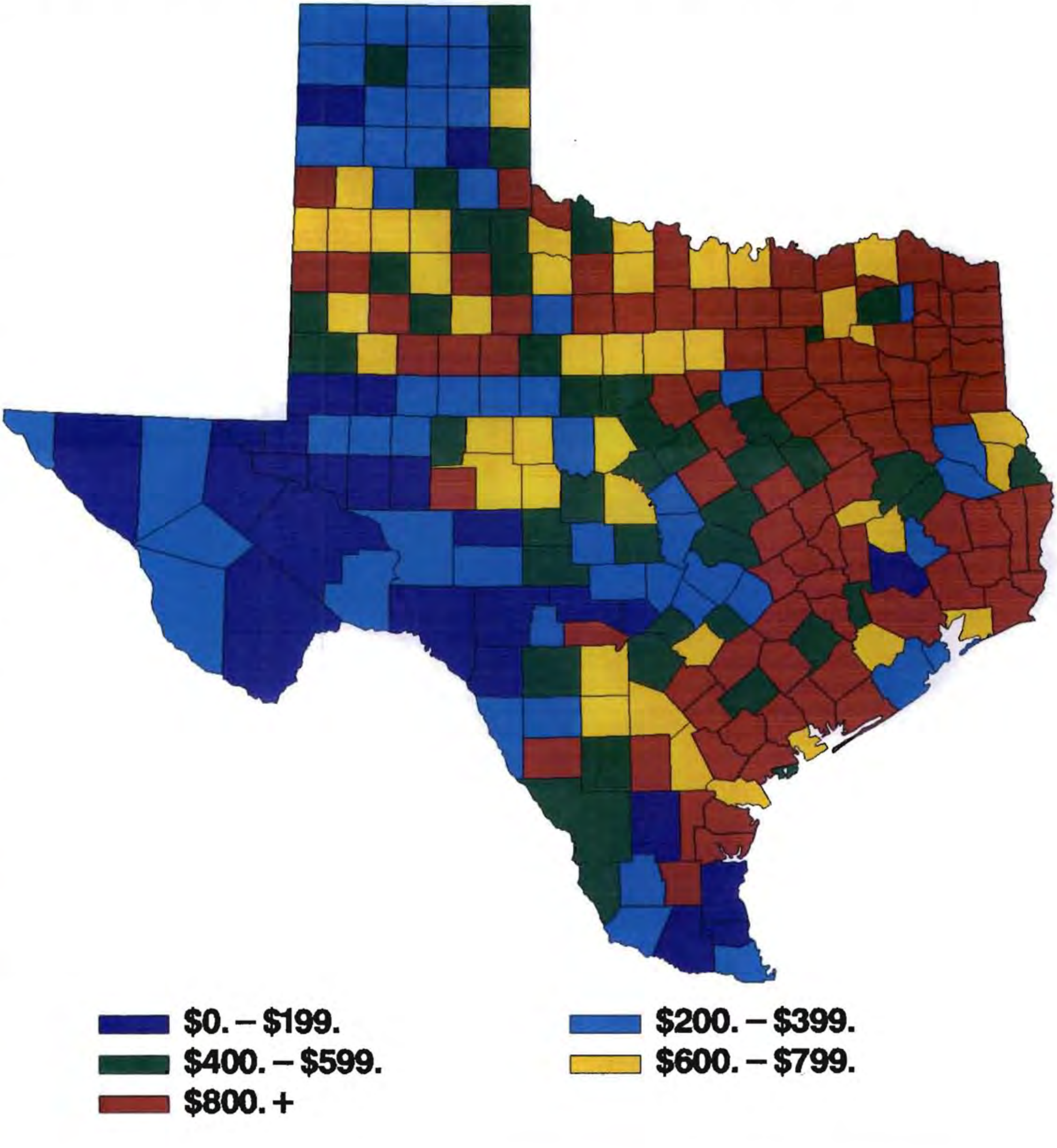
Figure 9.3 -- Maintenance Expenditures in Actual and FY84 Dollars, FY84-FY91.

Cost Per Lane Mile

The drop in construction expenditures shifted a larger burden to maintenance. This is most evident, when looking at maintenance cost per lane mile, as shown in Figure 9.4. This figure indicates that the eastern half of the state has higher maintenance expenditures per lane mile. It also shows that maintenance treatments are used in place of rehabilitation and reconstruction address these problems. Maintenance treatments instantly improve surface condition, but do not correct pavement structural problems. This results in close monitoring and constant maintenance of these pavements.

MAINTENANCE EXPENDITURES

1991 MMIS, SEGMENT 78 – ACP ONLY ($/LANE MILE)



-Notes-

SUMMARY OF CONSTRUCTION AND MAINTENANCE FUNDING

Construction and maintenance funds both dropped in FY91. Once inflation is included, the FY91 expenditures are below the 1986 levels. Thus inflation has removed the benefits of the fuel tax increases in 1985 and 1987. The construction funding reduction has shifted more burden of keeping the highway network in an acceptable condition to maintenance. Because maintenance treatments are being used to preserve the present condition, the structural integrity of pavements is not being maintained or improved. This is why ACP pavements have 30 percent rutting and 34 percent indicate poor pavement structures. The drop in maintenance funds in FY91 is reflected in the drop in overall condition in 1990.

-Notes-

CHAPTER 10
CONCLUSIONS

PES data indicates a slight decrease in the overall condition of the Texas highway network, the first after several consecutive years of improvement. This decrease can be attributed to reduced ride quality, increasing distress and reduced funding. Still, approximately 90 percent of the network was in good to very good condition.

ACP, the predominate pavement type, showed a slight decrease in condition. Cracking distresses were up while rutting and other distresses remained stable. The structural strength survey showed that 29.4 percent of the ACP in good to very good condition had "poor structure." This indicates that maintenance treatments are used in lieu of needed rehabilitation and reconstruction. In many cases, the symptoms are treated rather than solved. Funding constraints are most likely the cause of this practice.

CRC, the second most predominate pavement type, declined for the second straight year. Spalled cracks, punchouts, and asphalt patches all increased, while concrete patches decreased. This indicates that maintenance funds to properly correct these distresses are limited.

JCP, the least predominate pavement type, continued to be the pavement type in worst condition. In 1990, JCP showed a decrease in overall condition. This decrease in condition can be attributed to a decrease in ride quality and an increase in distresses. However, due to the small fluctuating sample size on JCP, the finding are suspect.

This year, probability programs using historical data were developed to project the future condition of ACP pavements. These programs indicate that a noticeable increase in ACP distresses can be expected over the next five years. Load-related distresses such as rutting, failures, and alligator cracking will contribute most to the drop in condition. Ride quality will increase, but may become difficult to maintain as load-related distresses in the surface evolve into base and subgrade problems. Continued reductions in construction and maintenance expenditures threaten to accelerate the rate of increasing distress.

However, rehabilitation needs decreased to approximately $512 million this year. This was down $27 million from last year's needs. A small portion (1 percent) of this decrease can be attributed to an incomplete conversion of PES data to the Texas Reference Marker system. Both ACP and CRC contributed to this decrease in spite of a $40 million increase in JCP rehabilitation needs.

The precision of the PES visual distress ratings was 79.5 percent ± 15 points in 1990. This was 2.7 percent less than last year and is mostly attributed to reduced rater precision on CRC distresses. Implementation of more automated data collection equipment is expected to improve repeatability of distress ratings.

CONDITION OF TEXAS PAVEMENTS
QUESTIONNAIRE

We hope that this report gives a better sense of the overall condition of Texas pavements. Please, help improve the value of future reports by filling out this questionnaire. D-18PM will review the results and make necessary changes to future reports.

Please, check the appropriate box on the usefulness of each chapter.

CHAPTER	VERY USEFUL	SOMEWHAT USEFUL	NO OPINION	NOT MUCH USE	NOT USEFUL AT ALL
EXECUTIVE SUMMARY					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

COMMENTS: ______________________________

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What else would you like to see?______________________________

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What would you like to see deleted?______________________________

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Would you like to see charts by District in the report?______________________________

Would you like to have charts for your District only?______________________________

*(Include name and phone number, if you want your District's charts.)*______________________________

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Return questionnaire to: **Texas Department of Transportation, D-18PM**
Attention: Bryan Stampley
125 E. 11th Street
Austin, Texas 78701-2483
or Fax STS 241-3681

If you have any questions about the questionnaire, please contact Mr. Scott Lambert at (512)465-7730 or STS 241-7730 or Mr. David Fink at (512)465-3066 or STS 241-3066.

Thank You for your cooperation!