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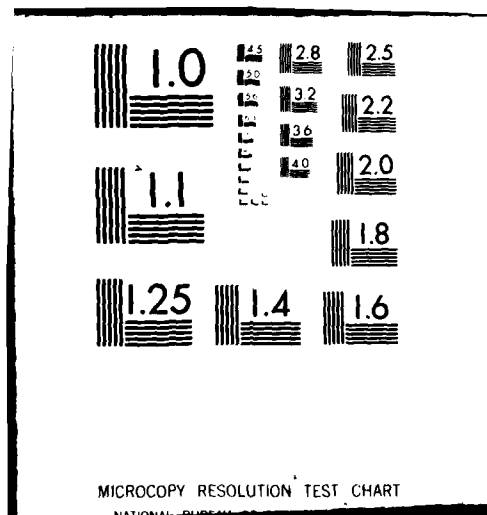
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OVERVIEW OF THE 'PAVER' PAVEMENT MANAGEMENT SYSTEM AND ECONOMIC--ETC(U)
MAR 82 M Y SHAHIN, S D KOHN

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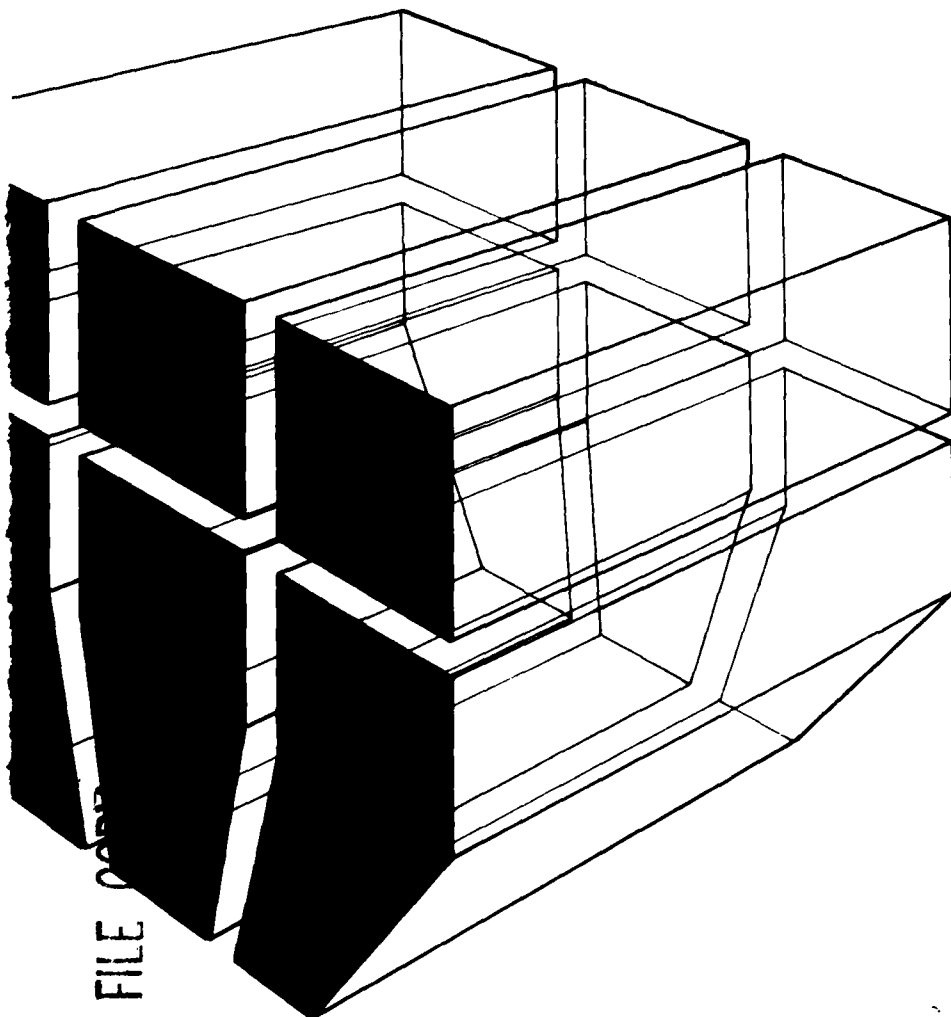
TECHNICAL MANUSCRIPT M-310
March 1982

OVERVIEW OF THE "PAVER"
PAVEMENT MANAGEMENT SYSTEM

and

ECONOMIC ANALYSIS OF FIELD IMPLEMENTING
THE "PAVER" PAVEMENT MANAGEMENT SYSTEM

by
M. Y. Shahin
S. D. Kohn



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presented are: data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning.

ECONOMIC ANALYSIS OF FIELD IMPLEMENTING THE "PAVER" PAVEMENT MANAGEMENT SYSTEM

The paper presents the results of an economic analysis performed on implementing the PAVER system at a military installation. PAVER is a pavement management system developed by the U.S. Army Corps of Engineers over the past 10 years for use by military installations, cities, and counties. It provides the user with practical management tools including data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning.

The economic analysis was performed based on data collected during a Prototype Evaluation Test (PET). The PET consisted of PAVER data gathering for the entire installation, and monitoring the utilization and cost of use of PAVER by the installation personnel. The PET consumed two years; however, the official cost-monitoring period was 4 months. The monitoring team consisted of 21 pavement engineers. Two economic analyses were performed: (1) an analysis based strictly on the data collected during the 4-month PET "PET Data Comparison," and (2) an analysis based on estimated times and costs for expected annual use "Estimated Data Comparison."

The results of the "PET Data Comparison" showed that the annual cost of pavement management using PAVER is approximately 50 percent that of the cost of the current operating method. The results of the "Estimated Data Comparison" showed that the annual cost of pavement management using PAVER is approximately 30 percent that of the current method.

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FOREWORD

These papers were prepared for presentation at the 61st Annual Meeting of the Transportation Research Board, held in January 1982.

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COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.



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OVERVIEW OF THE "PAVER" PAVEMENT MANAGEMENT SYSTEM

INTRODUCTION

"PAVER" is a pavement management system designed for use by military installations, cities, and counties. The system was developed and tested over the past 10 years and is currently being implemented by several agencies, including Fort Eustis, Great Lakes Naval Training Center, and the City of Mesa, Arizona. This system was developed by the U.S. Army Construction Engineering Research Laboratory under the auspices of the Office, Chief of Engineers, U.S. Army Corps of Engineers. It has been extensively tested prior to its implementation. The objective of this paper is to provide an overview of PAVER, with emphasis on what is available to the system users. Details of the system's development and results of an economic analysis of its implementation have been documented elsewhere (ref. 1, 2).

PAVER provides the engineer with a practical decision-making procedure for identifying cost-effective maintenance and repairs on roads and streets. The System 2000 is the database manager. This system and other "interface" programs provide the user with report generation capability for critical information. This information allows objective input to the decision-making process.

PAVER provides its users with many important capabilities. These include data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning. The following sections describe these capabilities and provide example reports for each area.

DATA STORAGE AND RETRIEVAL

The PAVER database is a custom-designed data structure defined on a commercially available computer database manager called System 2000. (System 2000 is a registered Trademark of the Intel Corp.)

The data structure consists of 12 data groups (see Figure 1) which are linked together to form a tree structure. Storing the data in this structure enables the user to retrieve information based on its connection to other data in the database. Space is available in each data group to store specific items related to that data group. The Pavement Structure data group shown in Figure 2 is an example.

The data can be stored and retrieved through special "interface" programs (Fortran or Cobol programs) or through the access language of the database manager. These programs are interactive, so the user has immediate access to the database. The programs are designed to supply the information in useful format.

PAVEMENT NETWORK DEFINITION

An installation's (city's) pavement network consists of all surface areas that provide accessways for the ground or air traffic (airfield pavements). This network must be divided and identified in order to use the database. Networks are divided into Branches, Sections, and Sample Units. Following are brief definitions of these items:

(1) A Branch is any identifiable part of the network which is a single entity and has a distinct function, such as an individual street.

(2) A Section is a division of a Branch which has consistent structural composition, construction history, and traffic volume.

(3) A Sample Unit is the smallest unit of the network and is an area of the pavement section used during inspection.

The database provides information on the pavement network through reports such as "Lists" or "Inventory." Figure 3 shows a typical output of the "Inventory" report. This report provides general information about specific Branches or Sections, thus providing the user with overall inventory information.

PAVEMENT CONDITION RATING

A key component of any pavement management system is a condition rating procedure. The PAVER system uses the Pavement Condition Index (PCI), a composite index of the pavement's structural integrity and operation condition. It is a numerical index from 0 to 100, with 100 representing excellent condition. The PCI is determined based on quantity, severity, and type of distress, as illustrated in Figure 4. The PCI was developed to agree closely with the collective judgment of experienced pavement engineers.

The PCI has been divided into seven condition categories, ranging from "excellent" to "failed," as shown in Figure 5. These categories are useful for developing maintenance policies and guidelines.

The PAVER database uses reports such as "PCI", "Inspect", and "Sample" to provide PCI information. Figure 6 shows a typical output of the "Inspect" report, which provides the user with PCI and distress information. The report can be used to prepare desk estimates of repairs and to determine history of pavement condition.

PROJECT PRIORITIZATION

Project prioritization is an immediate payoff of pavement network definition and pavement condition rating. The "PCI" report can be used for this purpose. It lists pavement sections in an increasing order of PCI. Figure 7 is an example report output. The information in the report can be sorted based on pavement surface type, pavement rank (functional class), traffic type and volume, PCI range, or a combination of factors. Therefore, the report can be used to prioritize projects based on the user's policy.

INSPECTION SCHEDULING

The inspection schedule report has been developed to maintain current condition data with efficient inspection level. This report produces a plot and list of the pavement sections to be surveyed for the next 6 years for any type of Branch Use (roadway, parking, etc.) and surface type (asphalt, Portland cement, concrete, etc.).

The schedule is based on two criteria. One is the minimum PCI a given pavement type is allowed to reach, and the second is the rate of deterioration (loss of PCI points per year). The user inputs the minimum PCI values and the years allowed between inspections for various deterioration rates. The PCI for the selected sections is then predicted by a straight line extrapolation, based on the maximum slope from either the last inspection or construction/overlay date (see Figure 8). Sections reaching the minimum PCI within 6 years or reaching the time limit based on the rate of deterioration will be selected for inspection in the appropriate year.

Figure 9 shows a typical Inspection Schedule output with plot and list of cases. The example shown is for primary roadways with asphalt concrete surfaces. Using this report, the engineer can keep the pavement network database up to date with minimum effort.

DETERMINATION OF PRESENT AND FUTURE NETWORK CONDITION

An overall frequency of condition report has been developed to help plan future M&R and to inform management of the network condition. The report shows an estimated frequency of condition (based on the PCI scale) for the year requested. The pavement sections included in the report can be selected based on Branch Use, Pavement Rank, and Surface Type.

The frequency is estimated as in the Inspection Schedule report, using a straight line extrapolation of the PCI. Figures 10 and 11 show typical outputs of this report. These two figures show the estimated frequency of occurrence for the same set of pavement sections for two different years. The extrapolation presumes no major repairs (such as slab replacement, overlay, etc.) have occurred between the last inspection and prediction dates. Thus, the impact of performing no major repairs can be seen.

DETERMINATION OF M&R NEEDS

A decision process has been devised for determining the M&R needs of a pavement section. Figure 12 is a flow diagram of this process. A first-level decision can be made, based on the PCI value, type of distress, and deterioration rate. PAVER provides reports such as PCI and Condition History to help the user make the first decision. The PCI report is an ordered listing of sections ranked by PCI (Figure 7). The Condition History report can be used to determine the rate of deterioration; the report plots the PCI over time for a given section. The plot shows the PCI at each inspection date and linearly extrapolates a point 5 years beyond the last inspection date. Figure 13 is an example of this report. The type of distress can be determined from the Inspect report, shown in Figure 6.

If a pavement section does not require further analysis, routine maintenance practices can be continued. Routine maintenance includes practices such as spall repair, crack filling, etc. Using maintenance guidelines for specific distress types, such as those shown in Table 1, the user can input a repair policy. This policy is used in a program called "MRG" to estimate the type and cost of routine repair to specific sections. The "MRG" report can also be used to compute the cost of overlay after distress repair. Figure 14 shows an output of the "MRG" report.

If a section requires further analysis, an evaluation summary is completed for the section. The evaluation is based on structural capacity, roughness, skid, and other relevant factors as shown in the top half of Figure 15. Complete guidelines for performing the evaluation are presented in ref. 1. Feasible M&R alternatives are identified based on the results of the evaluation as shown in the bottom half of Figure 15. This figure is an output of an Evaluation Summary report that was developed based on input from many experiences (maintenance engineers). The output from the report is general. Therefore, the engineer needs to select specific alternatives and perform the design based on the user agency policy. This may include using nondestructive testing.

PERFORMANCE OF ECONOMIC ANALYSIS

Several repair (or construction) alternatives may be considered feasible for any given pavement section. To help select the appropriate alternative, an economic analysis program has been developed and added to the system. The program allows the user to input initial costs, periodic maintenance costs, and separate future maintenance costs. Figure 16 shows a typical input, and Figure 17 gives a corresponding output. As shown, the user is provided with the initial cost, present value, equivalent uniform annual cost, and equivalent uniform annual cost per square yard.

The program allows the users to vary interest rates, inflation rates, repair costs, and timing so that their effect on alternatives can be easily analyzed. Figure 18 is an example analysis which shows the effect of interest and inflation rates.

BUDGET PLANNING

A Budget Planning report was developed to provide an estimate of the rehabilitation dollars required over a 10-year period for a given level of condition. The report is based on the user's input of minimum PCI levels for various Branch Uses and Pavement Rank. The user also inputs unit repair costs based on pavement Surface Type and the PCI scale; i.e., the cost of repair can be varied, depending on the PCI value. Thus, the increased cost of differing rehabilitation can be anticipated. The program also takes into account the inflation rate. Figure 19 shows an example output of this report.

This program predicts, for each pavement section, the year in which the minimum PCI is reached and calculates the cost of repair. The prediction is the straight-line prediction procedure explained in the Inspection Schedule report.

SUMMARY

This paper has presented a brief overview of PAVER--a pavement management system for military installations, cities, and counties. PAVER assists engineers and planners with pavement management by providing the database and computational capabilities. These capabilities are: data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning.

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2. Kohn, S. D., and M. Y. Shahin, "Economic Analysis of Field Implementing the PAVER Pavement Management System," technical paper submitted for presentation at the 1982 TRB annual meeting.

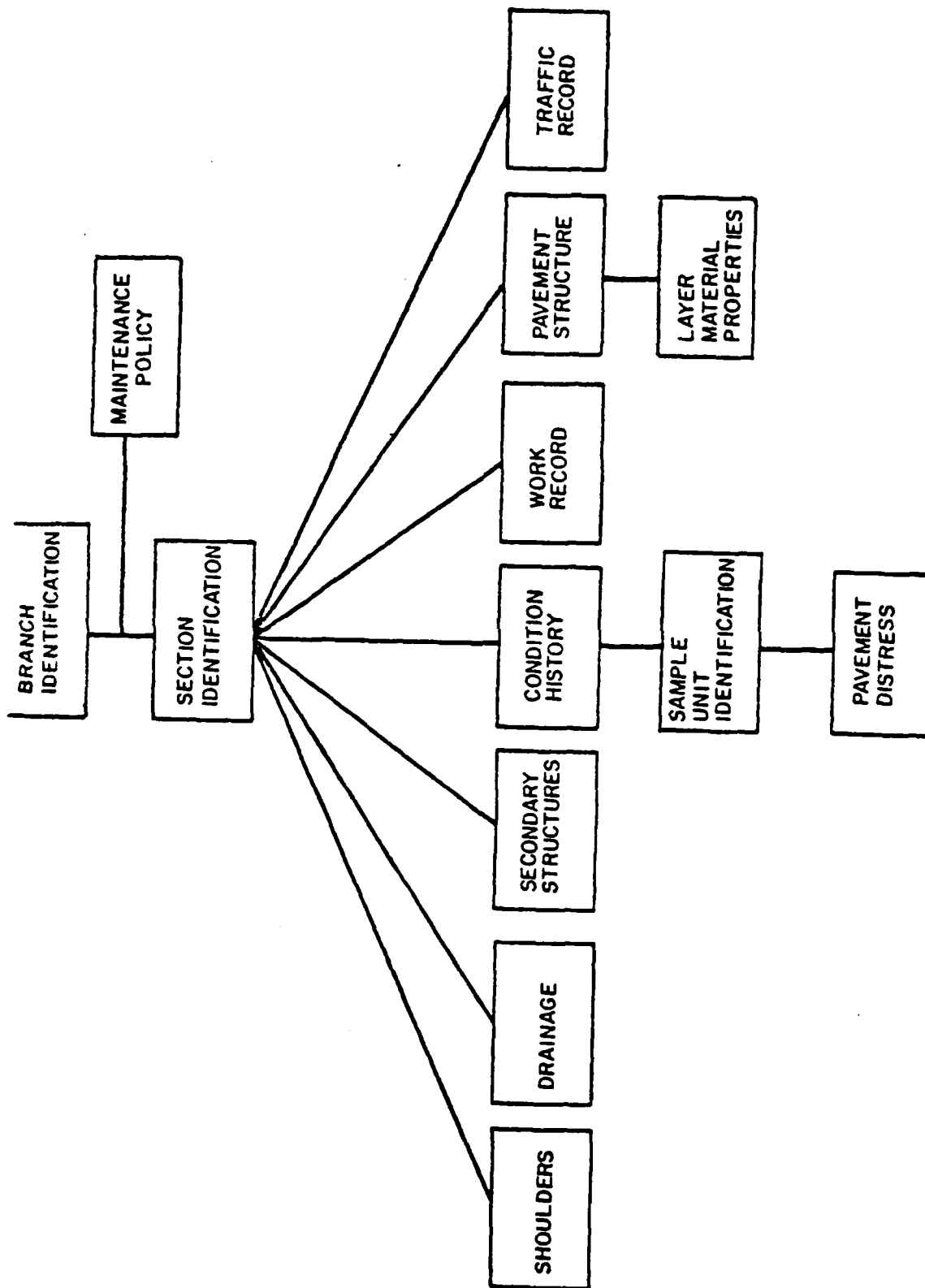


Fig 1. Paver Data Structure

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2500* PAVEMENT STRUCTURE (RG IN 1000)
2501* DATE CONSTRUCTED (DATE IN 2500)
2502* LAYER CATEGORY (NAME X(10) IN 2500)
2503* LAYER MATERIAL CODE (INTEGER NUMBER 999 IN 2500)
2504* LAYER MATERIAL (NAME X(20) IN 2500)
2505* LAYER THICKNESS (DECIMAL NUMBER 99.9 IN 2500)
2506* TYPE OF COATING (NAME X(10) IN 2500)
2507* LAYER COMMENTS (NON-KEY NAME X(39) IN 2500)
2508* PAVEMENT STRUCTURE UPDATE (NON-KEY DATE IN 2500)
2509* FACTOR 2509 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
2510* FACTOR 2510 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
2511* FACTOR 2511 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
2512* FACTOR 2512 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
2513* FACTOR 2513 (NON-KEY DECIMAL NUMBER 9(8).99 IN 2500)
2514* PSTR-CONCAT (NAME X(19) IN 2500)
3100* LAYER MATERIAL PROPERTIES (RG IN 2500)
3101* TEST DATE (DATE IN 3100)
3102* TEST TYPE (NAME X(31) IN 3100)
3103* TEST VALUE (DECIMAL NUMBER 9(5).9999 IN 3100)
3104* TEST UNIT (NON-KEY NAME X(13) IN 3100)
3105* FACTOR 3105 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
3106* FACTOR 3106 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
3107* FACTOR 3107 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
3108* FACTOR 3108 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
3109* FACTOR 3109 (NON-KEY DECIMAL NUMBER 9(8).99 IN 3100)
3110* LMAT-CONCAT (NAME X(26) IN 3100)

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Fig 2. Pavement Structure Data Group

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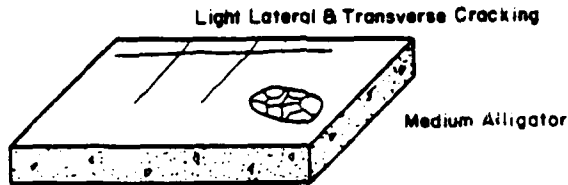
INVENTORY
NON-FAMILY HOUSING PAVEMENTS

	SURF TYPE	BRANCH USE	PAVEMENT RANK	AREA (SY)
----- IHWASN WASHINGTON NORTH				
SECTION 01	AC	ROADWAY	PRIMARY	4007
FROM- ROUTE 105				
TO- CL MADISON AVE				
SECTION 02	AC	ROADWAY	PRIMARY	6651
FROM- CL MADISON AVE				
TO- N'LY SIDE HINES CIR				
SECTION 03	AC	ROADWAY	PRIMARY	4000
FROM- S'LY SIDE HINES CIR				
TO- CENTER OF SOMERVELL				
SECTION 04	AC	ROADWAY	PRIMARY	6340
FROM- CENTER OF SOMERVELL				
TO- N'LY EDGE TAYLOR				
SECTION 05	PCC	ROADWAY	SECONDARY	4453
FROM- S'LY EDGE TAYLOR				
TO- N'LY EDGE WILSON				
			TOTAL BRANCH AREA	25451
			TOTAL AREA OF SELECTED NON-FAMILY HOUSING PAVEMENTS	25.451

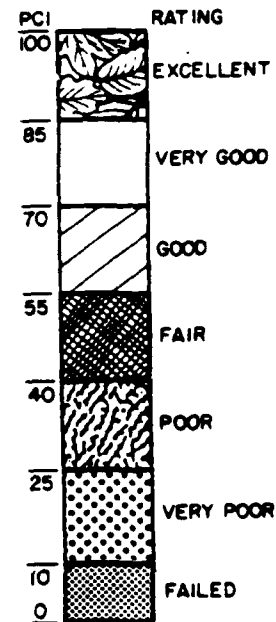
Fig 3. Example Output of Report "INV"

STEP 1. DIVIDE PAVEMENT SECTION INTO SAMPLE UNITS

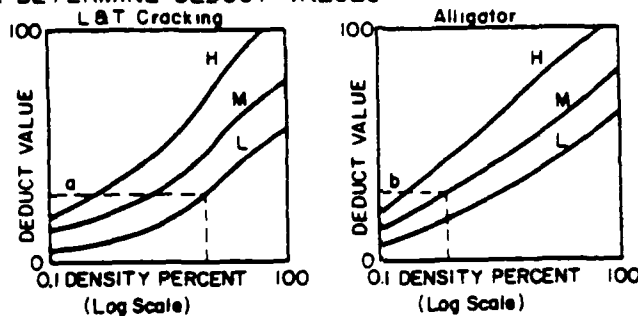
STEP 2. INSPECT SAMPLE UNITS. DETERMINE DISTRESS TYPES AND SEVERITY LEVELS AND MEASURE DENSITY.



STEP 8. DETERMINE PAVEMENT CONDITION RATING OF SECTION

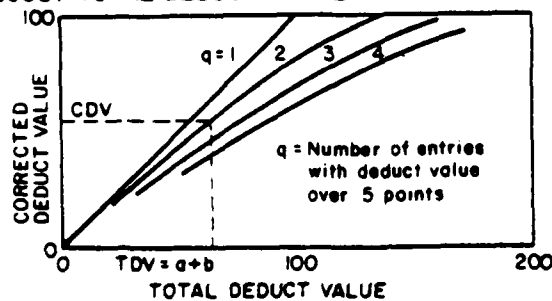


STEP 3. DETERMINE DEDUCT VALUES



STEP 4. COMPUTE TOTAL DEDUCT VALUE (TDV) $a+b$

STEP 5. ADJUST TOTAL DEDUCT VALUE



STEP 6. COMPUTE PAVEMENT CONDITION INDEX (PCI) $100 - CDV$ FOR EACH SAMPLE UNIT INSPECTED

STEP 7. COMPUTE PCI OF ENTIRE SECTION (AVERAGE PCI'S OF SAMPLE UNITS).

Fig 4. Steps for Determining PCI of a Pavement Section

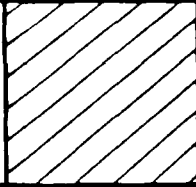
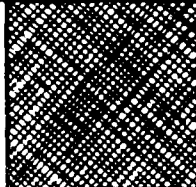
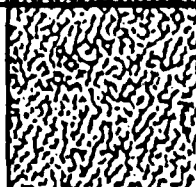
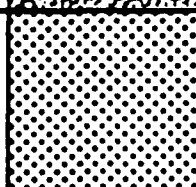
M & R ZONE	PCI		RATING
ROUTINE	100		EXCELLENT
	85		VERY GOOD
ROUTINE, MAJOR, OVERALL	70		GOOD
	55		FAIR
MAJOR, OVERALL	40		POOR
OVERALL	25		VERY POOR
	10		FAILED
	0		

Fig 5. Correlation of M&R Zones With PCI and Condition Rating for Airfield Pavements

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PAVEMENT INSPECTION

BRANCH NAME - WASHINGTON NORTH	SECTION LENGTH - 2307 LF
BRANCH NUMBER - IWASN	SECTION WIDTH - 24 LF
SECTION NUMBER - 04	SECTION AREA - 6340 SY

INSPECTION DATE - 11/06/79 PCI= 76 RATING= VERY GOOD
 CONDITION- RIDING-C2 SAFETY-C1 DRAINAGE-C1 SHOULDERS-C1 OVERALL-C1

TOTAL NUMBER OF SAMPLES IN SECTION=	24
NUMBER OF SAMPLES SURVEYED=	11
RECOMMENDED SAMPLES TO BE SURVEYED=	17
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED=	15.3

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION-

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
ALLIGATOR CR	MEDIUM	592 SF	1.03	21.4
DEPRESSION	LOW	5 SF	0.00	4.0
EDGE CR	HIGH	8 LF	0.01	7.4
EDGE CR	LOW	13 LF	0.02	0.2
EDGE CR	MEDIUM	30 LF	0.05	4.0
JT REFLECT CR	HIGH	74 LF	0.12	2.6
JT REFLECT CR	LOW	128 LF	0.22	0.0
JT REFLECT CR	MEDIUM	278 LF	0.48	3.8
LANE/SHLDR DROP	LOW	49 LF	0.08	2.0
LANE/SHLDR DROP	MEDIUM	25 LF	0.04	4.0
LONG/TRANS CR	LOW	512 LF	0.89	1.6
PATCH/UTIL CUT	LOW	192 SF	0.33	0.8
RR CROSSING	LOW	270 SF	0.47	2.0
RUTTING	LOW	150 SF	0.26	2.0
RUTTING	MEDIUM	72 SF	0.12	4.6

Fig 6. Example Output of Report "INSPECT"

REPORT DATE- 09/28/81

PCI REPORT

BRANCH NUMBER	BRANCH USE	SECTION NUMBER	PCI	RATING	SURFACE TYPE	SECTION AREA/SY	PAVEMENT RANK
PBENE	PARKING	01	10	FAILED	AC	440	SECONDARY
	12/04/79 [FROM] PARKING AREA				[TO]	BLDG 1002	
PBENE	PARKING	03	10	FAILED	AC	440	SECONDARY
	12/04/79 [FROM] PARKING AREA NR BLD				[TO]	G 1001	
PSTER	PARKING	03	13	VERY POOR	PCC	868	TERTIARY
	10/17/79 [FROM] PARKING LOT				[TO]	BLDG 515	
PBENE	PARKING	02	18	VERY POOR	AC	440	SECONDARY
	12/04/79 [FROM] PARKING AREA NR BLD				[TO]	G 1004	
IBACK	ROADWAY	01	21	VERY POOR	AC	5155	TERTIARY
	02/11/81 [FROM] E EDGE HARRISON RD				[TO]	W EDGE MULBRY IS RD	
PBENE	PARKING	04	25	VERY POOR	AC	440	SECONDARY
	12/04/79 [FROM] PARKING AREA NR BLD				[TO]	G 1005	
PCOND	PARKING	01	25	VERY POOR	PCC	550	SECONDARY

Fig 7. Example Output of Report "PCI"

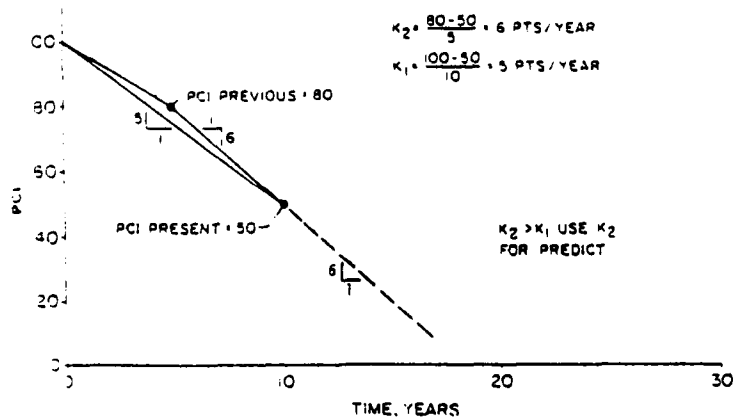
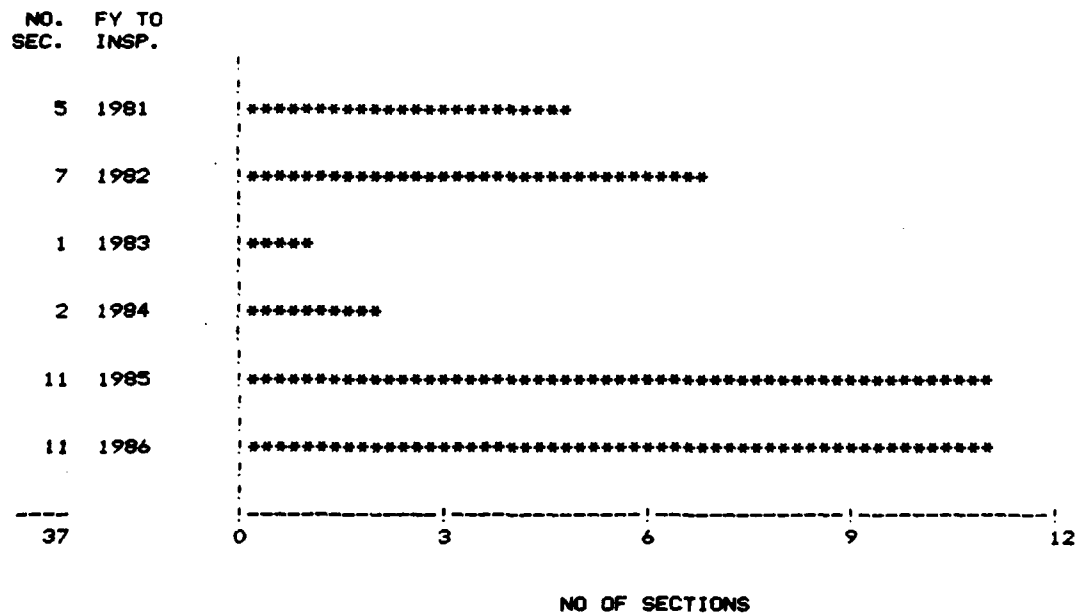


Fig 8. Example Case of PCI Prediction When PCI Was Previously Determined

INSPECTION SCHEDULE REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC
FAMILY HOUSING: B



TOTAL NO. OF SECTION: 37
SECT. NOT NEEDING REPAIR: 0
NO. OF MISSING VALUE: 1

Fig 9. Example Output of Report "SCHED"

INSPECTION SCHEDULE REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC
FAMILY HOUSING: B

LIST OF CASES IN
INSPECTION SCHEDULE REPORT

FY TO INSPECT : 1981					NO. OF SECTIONS : 5		
BRANCH NUMBER	BRANCH USE	SECT. NO.	PAVE. RANK	SUT	SEC FROM	TO	
ILEEB	ROADWAY	05	P	AC	7688 W'LY SIDE ANDERSON	HINES CIR	
IMULB	ROADWAY	02	P	AC	12551 N EDGE WILSON AVE	ENTR PINES GOLF CLB	
IWASN	ROADWAY	02	P	AC	6651 CL MADISON AVE	N'LY SIDE HINES CIR	
IWASN	ROADWAY	03	P	AC	4000 S'LY SIDE HINES CIR	CENTER OF SOMERVELL	
IWASN	ROADWAY	04	P	AC	6340 CENTER OF SOMERVELL	N'LY EDGE TAYLOR	

FY TO INSPECT : 1982					NO. OF SECTIONS : 7		
BRANCH NUMBER	BRANCH USE	SECT. NO.	PAVE. RANK	SUT	SEC FROM	TO	
ILEEB	ROADWAY	02	P	AC	2493 W'LY EDGE TAYLOR	CENTER KERR ROAD	
IMADI	ROADWAY	01	P	AC	823 E'LY EDGE WASH SO	W'LY EDGE WASH NO	
IPERS	ROADWAY	03	P	AC	1917 S'LY SIDE HAGOOD ST	CL WILSON AVE	
IWASN	ROADWAY	01	P	AC	4007 ROUTE 105	CL MADISON AVE	
IWASS	ROADWAY	01	P	AC	2999 ROUTE 105	BUS STA ENTRANCE	
IWASS	ROADWAY	06	P	AC	978 CENTER DARCY PL	S'LY SIDE SHEPPARD	
IWASS	ROADWAY	07	P	AC	5148 S'LY SIDE SHEPPARD	N'LY EDGE TAYLOR	

FY TO INSPECT : 1983					NO. OF SECTIONS : 1		
BRANCH NUMBER	BRANCH USE	SECT. NO.	PAVE. RANK	SUT	SEC FROM	TO	
IHINE	ROADWAY	01	P	AC	6586 END LEE 05	CCW TO END LEE 05	

FY TO INSPECT : 1984					NO. OF SECTIONS : 2		
BRANCH NUMBER	BRANCH USE	SECT. NO.	PAVE. RANK	SUT	SEC FROM	TO	
IMADI	ROADWAY	06	P	AC	1781 N EDGE PATTON	END AC PAVEMENT	
ITAYL	ROADWAY	02	P	AC	11806 50 FT W OF HARRISON	W'LY SIDE WASH SO	

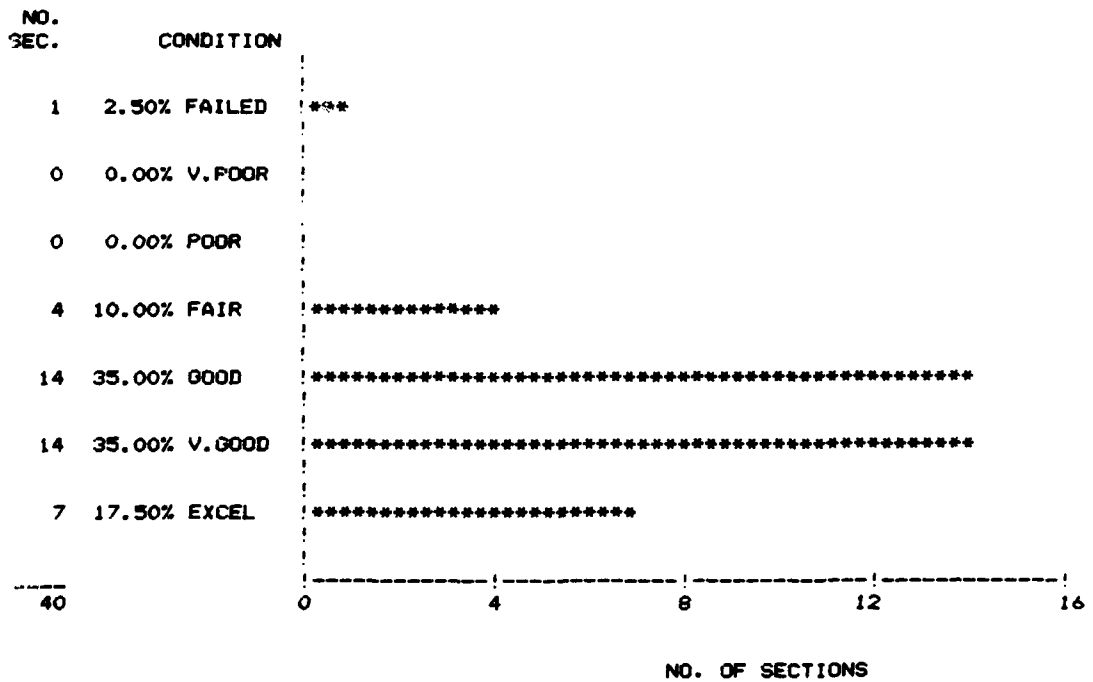
Fig 9. Example Output of Report "SCHED" (Continued)

PCI FREQUENCY REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC PCC
FAMILY HOUSING: B

YR= 1982



TOTAL NO. OF SECTION: 40
AVERAGE PCI: 70
NO. OF MISSING VALUE: 1

Fig 10. Example Output of Report "REQ" for January 1982

PCI FREQUENCY REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC PCC
FAMILY HOUSING: B

LIST OF SECTIONS IN
PCI FREQ REPORT
YR= 1982/01

BRANCH NUMBER	BRANCH USE	SECT. NO.	CUR PCI	PRO PCI	---FROM---	---TO---
INASN	ROADWAY	04	29	0	CENTER OF SOMERVELL	N'LY EDGE TAYLOR
ILEEB	ROADWAY	05	65	47	W'LY SIDE ANDERSON	HINES CIR
INASN	ROADWAY	03	64	49	S'LY SIDE HINES CIR	CENTER OF SOMERVELL
IMULB	ROADWAY	02	57	52	N EDGE WILSON AVE	ENTR PINES GOLF CLB
INASN	ROADWAY	02	68	52	CL MADISON AVE	N'LY SIDE HINES CIR
INASS	ROADWAY	01	82	56	ROUTE 105	BUS STA ENTRANCE
INASN	ROADWAY	01	72	59	ROUTE 105	CL MADISON AVE
IPERS	ROADWAY	03	66	59	S'LY SIDE HAGOOD ST	CL WILSON AVE
INASS	ROADWAY	06	72	59	CENTER DARCY PL	S'LY SIDE SHEPPARD
INASS	ROADWAY	07	74	61	S'LY SIDE SHEPPARD	N'LY EDGE TAYLOR
ILEEB	ROADWAY	02	76	63	W'LY EDGE TAYLOR	CENTER KERR ROAD
IMADI	ROADWAY	01	87	65	E'LY EDGE WASH SO	W'LY EDGE WASH NO
ITAYL	ROADWAY	02	71	65	50 FT W OF HARRISON	W'LY SIDE WASH SO
IMADI	ROADWAY	07	69	66	END AC PAVEMENT	N EDGE TAYLOR AVE
ITAYL	ROADWAY	04	70	68	E'LY SIDE WASH NO	END CONC PAVEMENT
IHINE	ROADWAY	01	88	69	END LEE 05	CCW TO END LEE 05
IMADI	ROADWAY	06	77	69	N EDGE PATTON	END AC PAVEMENT
IPERS	ROADWAY	02	74	70	ENTRANCE BLDG 1702	S'LY SIDE HAGOOD ST
IMULB	ROADWAY	05	73	70	RR BY PISTOL RANGE	250 FT W BLDG 3905
IMULB	ROADWAY	01	76	73	S EDGE TAYLOR AVE	N EDGE WILSON AVE
IMADI	ROADWAY	03	81	74	N'LY SIDE JEFFERSON	N'LY SIDE REINECKER
IMULB	ROADWAY	03	78	75	ENTR PINES GOLF CLB	RR AT PISTOL RANGE
INASS	ROADWAY	04	82	75	CENTER DILLON CIR	N'LY SIDE HINES CIR
IMADI	ROADWAY	02	83	76	E'LY EDGE WASH NO	N'LY SIDE JEFFERSON
INASS	ROADWAY	03	83	76	N'LY EDGE MADISON	CENTER DILLON CIR
ILEEB	ROADWAY	03	86	78	CENTER KERR ROAD	W EDGE LUCAS PLACE
INASS	ROADWAY	05	82	78	S'LY EDGE HINES CIR	CENTER DARCY PL
ILEEB	ROADWAY	06	86	79	E SIDE HINES CIR	W'LY EDGE MADISON
ITAYL	ROADWAY	03	88	81	W'LY SIDE WASH SO	E'LY SIDE WASH NO
IMADI	ROADWAY	04	86	81	N'LY SIDE REINECKER	CENTER LEE BLVD
ILEEB	ROADWAY	04	89	83	W'LY SIDE LUCAS PL	W'LY SIDE ANDERSON
IPERS	ROADWAY	01	92	84	E'LY EDGE MADISON	ENTRANCE BLDG 1702
IPERS	ROADWAY	04	86	84	CL WILSON AVE	OFFICERS CLUB
IMADI	ROADWAY	05	90	86	CENTER LEE BLVD	N'LY EDGE PATTON AV
ITAYL	ROADWAY	01	92	87	S'LY EDGE LEE BLVD	50 FT W OF HARRISON
IWILS	ROADWAY	02	92	89	E'LY EDGE MULB IS	CENTER OF IRWIN ST
IEUST	ROADWAY	01	96	91	S EDGE WARWICK BLVD	W EDGE WASH BLVD SO
INASS	ROADWAY	02	94	91	BUS STA ENTRANCE	N'LY SIDE MADISON
ITAYL	ROADWAY	05	93	91	BEGIN ASPH PAVEMENT	N'LY EDGE WILSON AV
IWILS	ROADWAY	03	96	94	CENTER OF IRWIN ST	W'LY EDGE PERSHING

TOTAL NO. OF SECTION: 40
AVERAGE PCI: 70
NO. OF MISSING VALUE: 1

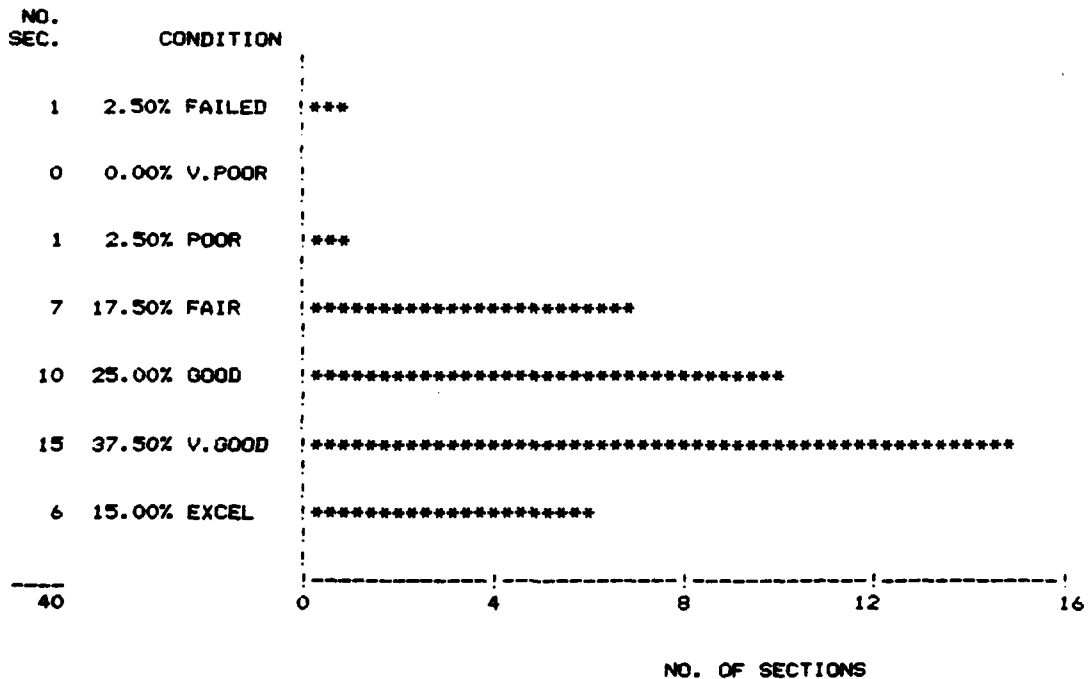
Fig 10. Example Output of Report "FREQ" for January 1982 (Continued)

PCI FREQUENCY REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC PCC
FAMILY HOUSING: B

YR= 1983/01



TOTAL NO. OF SECTION: 40
AVERAGE PCI: 67
NO. OF MISSING VALUE: 1

Fig 11. Example Output of Report "FREQ" for January 1983

PCI FREQUENCY REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC PCC
FAMILY HOUSING: B

LIST OF SECTIONS IN PCI FREQ REPORT YR= 1983/01

BRANCH NUMBER	BRANCH USE	SECT. NO.	CUR PCI	PRO PCI	---FROM---	---TO---
IWASN	ROADWAY	04	29	0	CENTER OF SOMERVELL	N'LY EDGE TAYLOR
ILEEB	ROADWAY	05	65	39	W'LY SIDE ANDERSON	HINES CIR
IWASN	ROADWAY	03	64	42	S'LY SIDE HINES CIR	CENTER OF SOMERVELL
IWASS	ROADWAY	01	82	44	ROUTE 105	BUS STA ENTRANCE
IWASN	ROADWAY	02	68	45	CL MADISON AVE	N'LY SIDE HINES CIR
IMULB	ROADWAY	02	57	50	N EDGE WILSON AVE	ENTR PINES GOLF CLB
IWASN	ROADWAY	01	72	52	ROUTE 105	CL MADISON AVE
IWASS	ROADWAY	06	72	52	CENTER DARCY PL	S'LY SIDE SHEPPARD
IMADI	ROADWAY	01	87	55	E'LY EDGE WASH SO	W'LY EDGE WASH NO
IWASS	ROADWAY	07	74	56	S'LY SIDE SHEPPARD	N'LY EDGE TAYLOR
IPERS	ROADWAY	03	66	57	S'LY SIDE HAGOOD ST	CL WILSON AVE
ILEEB	ROADWAY	02	76	58	W'LY EDGE TAYLOR	CENTER KERR ROAD
IHINE	ROADWAY	01	88	61	END LEE OS	CCW TO END LEE OS
ITAYL	ROADWAY	02	71	63	50 FT W OF HARRISON	W'LY SIDE WASH SO
IMADI	ROADWAY	06	77	65	N EDGE PATTON	END AC PAVEMENT
IMADI	ROADWAY	07	69	65	END AC PAVEMENT	N EDGE TAYLOR AVE
ITAYL	ROADWAY	04	70	67	E'LY SIDE WASH NO	END CONC PAVEMENT
IPERS	ROADWAY	02	74	68	ENTRANCE BLDG 1702	S'LY SIDE HAGOOD ST
IMULB	ROADWAY	05	73	68	RR BY PISTOL RANGE	250 FT W BLDG 3905
IMADI	ROADWAY	03	81	71	N'LY SIDE JEFFERSON	N'LY SIDE REINECKER
IWASS	ROADWAY	04	82	71	CENTER DILLON CIR	N'LY SIDE HINES CIR
IMULB	ROADWAY	01	76	72	S EDGE TAYLOR AVE	N EDGE WILSON AVE
IWASS	ROADWAY	03	83	73	N'LY EDGE MADISON	CENTER DILLON CIR
IMADI	ROADWAY	02	83	74	E'LY EDGE WASH NO	N'LY SIDE JEFFERSON
IMULB	ROADWAY	03	78	74	ENTR PINES GOLF CLB	RR AT PISTOL RANGE
ILEEB	ROADWAY	03	86	75	CENTER KERR ROAD	W EDGE LUCAS PLACE
ILEEB	ROADWAY	06	86	75	E SIDE HINES CIR	W'LY EDGE MADISON
IWASS	ROADWAY	05	82	76	S'LY EDGE HINES CIR	CENTER DARCY PL
IMADI	ROADWAY	04	86	78	N'LY SIDE REINECKER	CENTER LEE BLVD
ITAYL	ROADWAY	03	88	79	W'LY SIDE WASH SO	E'LY SIDE WASH NO
IPERS	ROADWAY	01	92	80	E'LY EDGE MADISON	ENTRANCE BLDG 1702
ILEEB	ROADWAY	04	89	80	W'LY SIDE LUCAS PL	W'LY SIDE ANDERSON
IPERS	ROADWAY	04	86	83	CL WILSON AVE	OFFICERS CLUB
IMADI	ROADWAY	05	90	84	CENTER LEE BLVD	N'LY EDGE PATTON AV
ITAYL	ROADWAY	01	92	86	S'LY EDGE LEE BLVD	50 FT W OF HARRISON
IEUST	ROADWAY	01	96	88	S EDGE WARWICK BLVD	W EDGE WASH BLVD SO
IWILS	ROADWAY	02	92	88	E'LY EDGE MULB IS	CENTER OF IRWIN ST
IWASS	ROADWAY	02	94	90	BUS STA ENTRANCE	N'LY SIDE MADISON
ITAYL	ROADWAY	05	93	91	BEGIN ASPH PAVEMENT	N'LY EDGE WILSON AV
IWILS	ROADWAY	03	96	94	CENTER OF IRWIN ST	W'LY EDGE PERSHING

TOTAL NO. OF SECTION: 40
AVERAGE PCI: 67
NO. OF MISSING VALUE: 1

Fig 11. Example Output of Report "FREQ" for January 1983 (Continued)

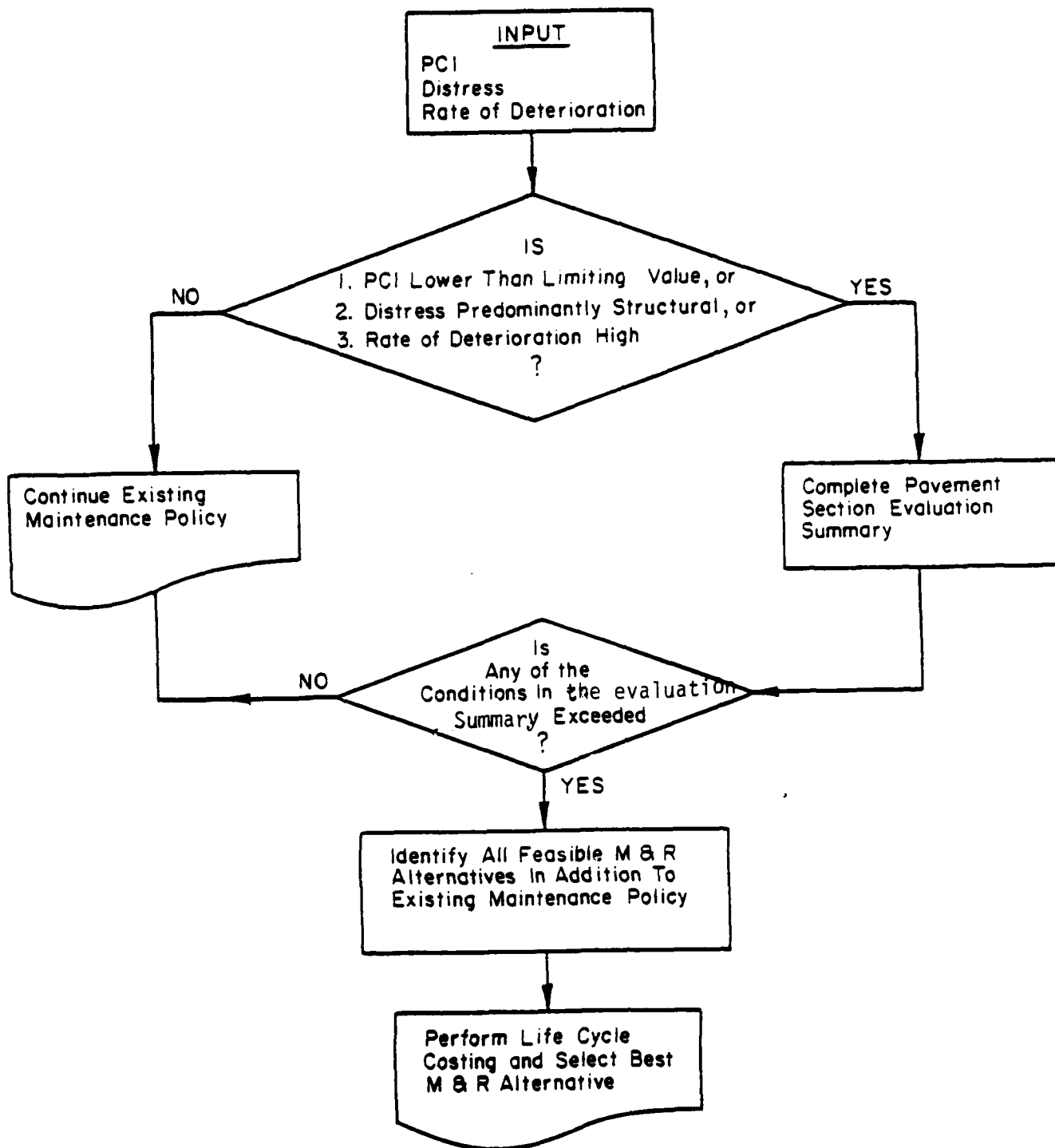


Fig 12. Flow Diagram of the Decision Process for Determining M&R Needs

CONDITION HISTORY

REPORT DATE: 81/09/28.

BRANCH NAME: WASHINGTON NORTH
 BRANCH USE: ROADWAY
 SECTION NUMBER: 04
 PAVEMENT RANK: PRIMARY
 SURFACE TYPE: AC

	DATE	PCI
CONST/OVERLAY	75/06	100
INSP	79/11	76
INSP	81/02	29
PRED	1981	0

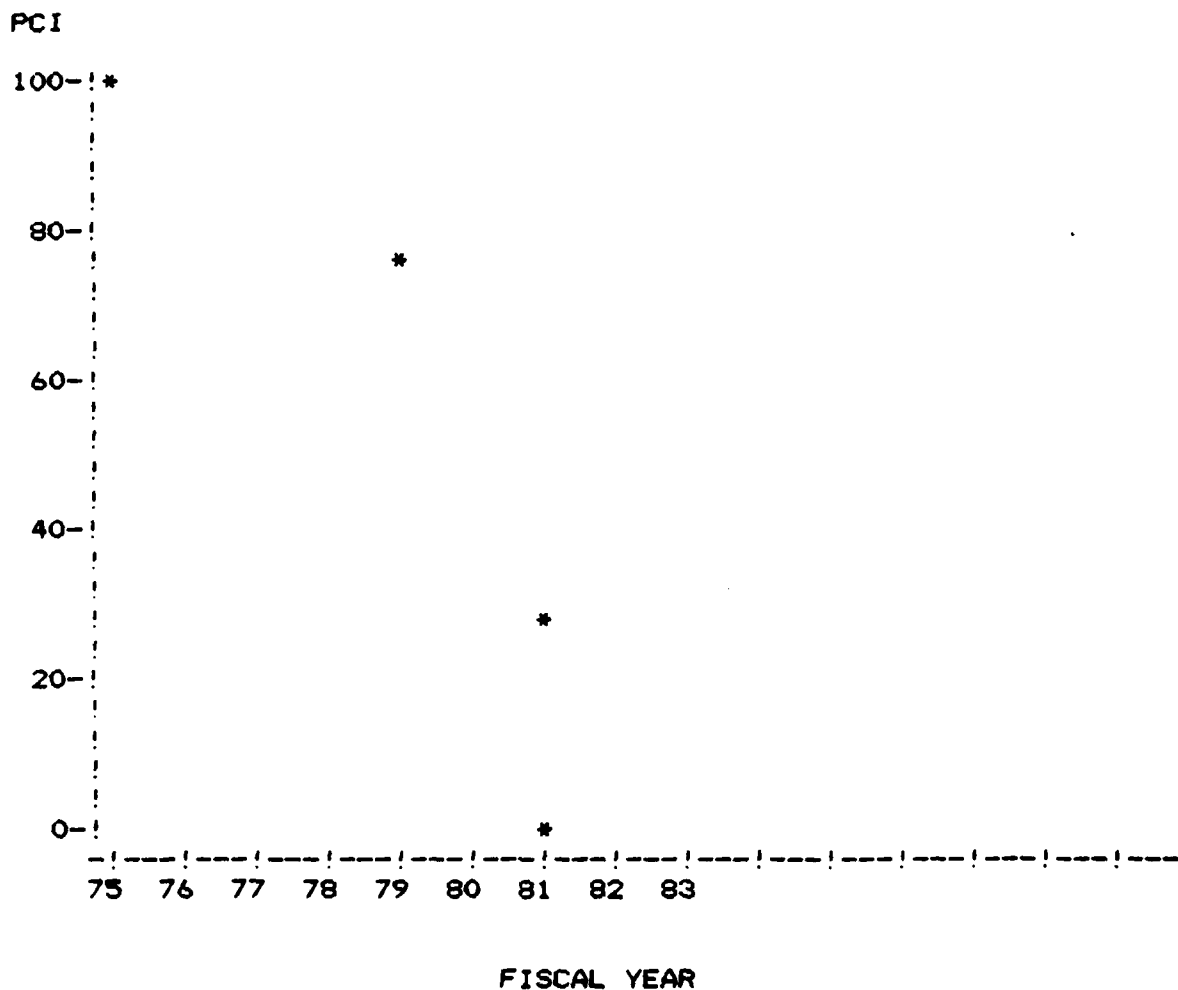


Fig 13. Example Output of Report "CNDHIST"

REPORT DATE - 01/10/05.

MAINTENANCE AND REPAIR GUIDELINES

BRANCH NAME - WASHINGTON NORTH SECTION LENGTH - 2307 LF
 BRANCH NMNR - IHASN SECTION WIDTH - 24 LF
 SECTION NMNR - 04 SECTION AREA - 6340 SY

INSPECTION DATE - 02/11/81

SECTION PCI - 29

DISTRESS TYPE	DIS SEV	DIST-QTY WORK-QTY	WORK TYPE	MATL CODE	LABOR HOURS	LABOR COST\$	MAT'L COST\$	EQUIP COST\$	TOTAL COST\$
ALLIGATOR CR	M	1682 SF							
		1682 SF	SHALLOW PATCH	120	841.0	10092	336	1867	13136
LONG/TRANS CR	M	975 LF							
		975 LF	CRACK FILLING	171	0.0	0	0	0	633
			OVERLAY	120					19020
				TOTAL	841.0	10092	336	1867	32789

Fig 14. Example Output of Report "MRG"

CURRENT VALUES ARE AS FOLLOWS :-
 1 PCI := 29
 2 LOCAL VARIATION(Y,N) := N
 3 SYSTEMATIC VARIATION(Y,N) := N
 4 SHORT TERM RATE OF DETERIORATION(L,N,H) := H
 5 LONG TERM RATE OF DETERIORATION(L,N,H) := H
 6 MAJOR SOURCE OF DISTRESS(LOAD,CLIMATE) := L
 7 LOAD CARRYING DEFICIENCY(Y,N) := Y
 8 SURFACE ROUGHNESS(L,N,H) := L
 9 SKID/HYDROPLANING PROBLEMS(L,N,H) := L
 10 PREVIOUS MAINTENANCE(L,N,H) := N
 SELECT(A-D) :=
 IDC

DATE := 29 SEP 81 FEASIBLE M&R ALTERNATIVES

BASE := M Y SHAMIN FEATID := WASH PCI := 29
 FEATNM := WASHINGTON BLVD M&R REPAIR ZONE := MAJOR-OVERALL

***** RECOMMENDED MAINTENANCE ALTERNATIVES *****

1 := RECONSTRUCTION
 2 := OVERLAY STRUCTURAL AC
 4 := OVERLAY PCC
 11 := RECYCLE STRUCTURE

*** END ***

Fig 15. Example Output of Report "EVAL"

M&R ACTIVITY DESC	YEAR	COST	TIME-SPACING
1 6 IN GRAN. \$10/TON	1982	32630.00	0
2 PRIME .8.27/SY	1982	3802.00	0
3 4 IN AC .830/TON	1982	38704.00	0
4 REP 2 1.5 INT COST	1987	3734.00	5
5 PATCH & MAINT. .05/SY	1988	704.00	1
6 SURF SEAL .8.1/SY	1989	1408.00	0
7 SURF SEAL .8.1/SY	1996	1408.00	0

Fig 16. Typical Input to Economic Analysis Program

DATE:= 81/09/28.

PROJECTED COST ANALYSIS

(DETAIL)

SECTION ID:=TW
 ALTERNATIVE:= 4N IN AC/6 IN GRAN SECTION AREA(S.Y.):= 14080.0
 LIFE OF ALTERNATIVE:= 20 INTEREST RATE:= 10.0 INFLATION RATE:= 0.0

M&R ACTIVITY	YEAR	COST(\$)	PRESENT VALUE(\$)
6 IN GRAN,\$10/TON	1982	32630.00	32630.00
PRIME,\$.27/SY	1982	3802.00	3802.00
IN AC,\$30/TON	1982	88704.00	88704.00
TOTAL:=		125136.00	125136.00
REP 2%,1.5 INT COST	1987	3754.00	2330.94
PATCH & MAINT,.05/SY	1988	704.00	397.39
PATCH & MAINT,.05/SY	1989	704.00	361.26
SURF SEAL,\$.1/SY	1989	1408.00	722.53
TOTAL:=		2112.00	1083.79
PATCH & MAINT,.05/SY	1990	704.00	328.42
PATCH & MAINT,.05/SY	1991	704.00	298.56
REP 2%,1.5 INT COST	1992	3754.00	1447.33
PATCH & MAINT,.05/SY	1992	704.00	271.42
TOTAL:=		4458.00	1718.75
PATCH & MAINT,.05/SY	1993	704.00	246.75
PATCH & MAINT,.05/SY	1994	704.00	224.32
PATCH & MAINT,.05/SY	1995	704.00	203.92
PATCH & MAINT,.05/SY	1996	704.00	185.39
SURF SEAL,\$.1/SY	1996	1408.00	370.77
TOTAL:=		2112.00	556.16
REP 2%,1.5 INT COST	1997	3754.00	898.68
PATCH & MAINT,.05/SY	1997	704.00	168.53
TOTAL:=		4458.00	1067.21
PATCH & MAINT,.05/SY	1998	704.00	153.21
PATCH & MAINT,.05/SY	1999	704.00	139.28
PATCH & MAINT,.05/SY	2000	704.00	126.62
PATCH & MAINT,.05/SY	2001	704.00	115.11
INITIAL COST(\$):=		125136.00	
PRESENT VALUE(\$):=		134126.43	
EQUIVALENT UNIFORM ANNUAL COST(\$):=		15754.44	
EUAC PER SQ. YD. (\$):=		1.12	

----- END OF REPORT -----

Fig 17. Economic Analysis Output for Input Shown in Fig 15

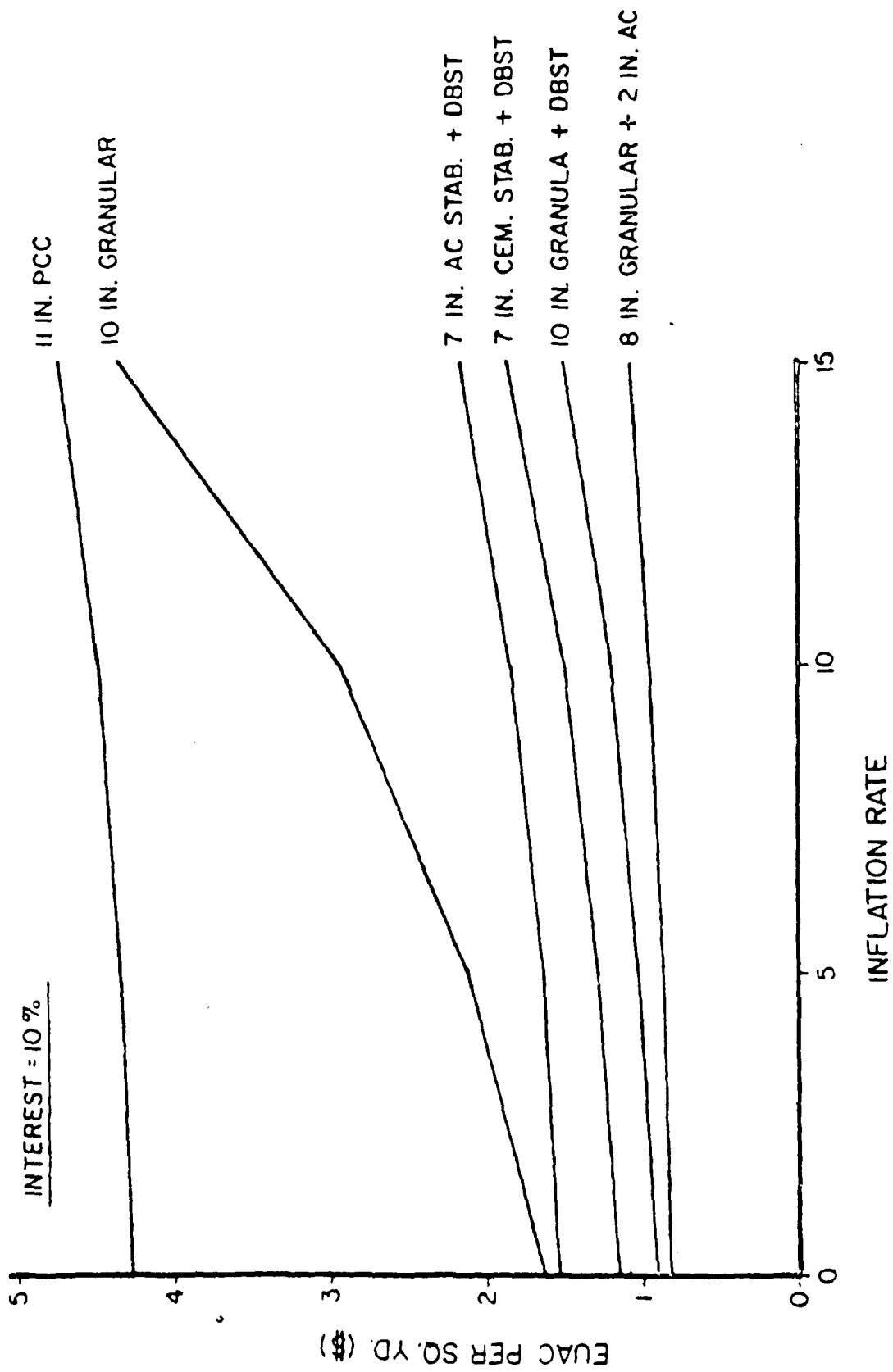
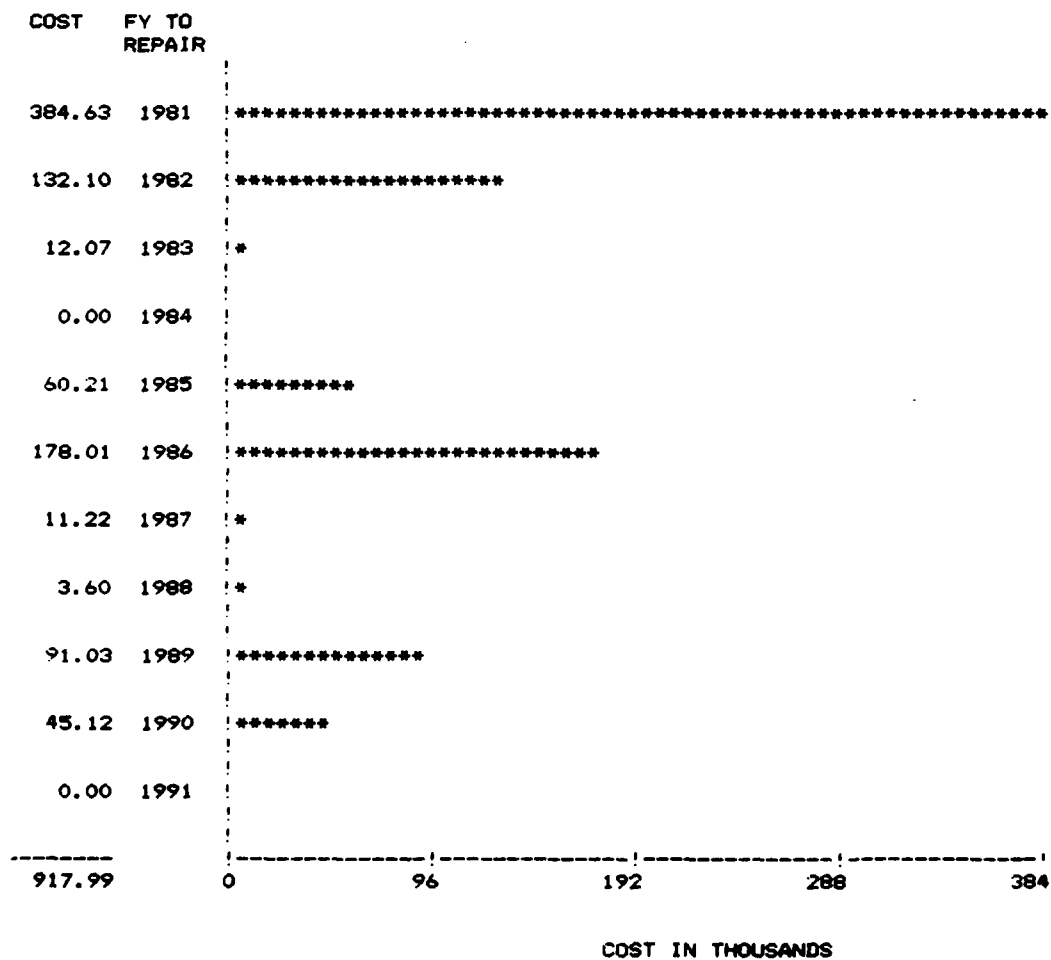


Fig 18. Example Equivalent Uniform Annual Cost (EUAC) per SY for Various Alternatives

BUDGET PLANNING REPORT

REPORT DATE: 81/09/28.

BRANCH USE: ROADWAY
PAVEMENT RANK: P
SURFACE TYPE: AC
INFLATION RATE: 10.00
FAMILY HOUSING: B



TOTAL NO. OF SECTION: 28
SECT. NOT NEEDING REPAIR: 9
NO. OF MISSING VALUE: 1

Fig 19. Example Output of Report "BUDPLAN"

TABLE 1. MAINTENANCE GUIDELINES FOR ASPHALT PAVEMENT DISTRESSES

Distress Type	MAR Method											Notes
		Do Nothing	Crack Seal	Partial Depth Patch	Full Depth Patch	Skin Patch	Pothole Filling	Apply Heat & Roll Sand	Apply Surface Seal Emulsion	Apply Rejuvenation	Apply Aggregate Seal Coat	
1 Alligator Cracking				M,H	M,H				L	L		
2 Bleeding		L						L,M,H				
3 Block Cracking		L	L,M,H							L	L,M	
4 Bumps & Sags		L		M,H	M,H	M,H						
5 Corrugation		L		M,H	M,H							
6 Depression		L		M,H	M,H	M,H						
7 Edge Cracking		L	L,M	M,H	M,H							If predominant, apply shoulder seal, e.g., aggregate seal coat
8 Joint Reflective Cracking		L	L,M,H	H								
9 Lane/Shoulder Drop Off		L										If predominant, level off shoulder and apply aggregate seal coat
10 Longitudinal Transverse Cracking		L	L,M,H	H					L	L	L,M	
11 Patching & Utility Cut		L	M	H*	H*							*Replace patch
12 Polished Aggregate		A									A	
13 Potholes				L	L,M,H		L,M,H					
14 Railroad Crossing		L				L,M,H						
15 Rutting		L		L,M,H	M,H	L,M,H						
16 Shoving		L		M,H								
17 Slippage Cracking		L	L	M,H								
18 Swell		L			M,H							
19 Weathering & Raveling		L		H					L,M	L	M,H	

Note: L = low severity; M = medium severity; H = high severity; A = has only one severity level.

ECONOMIC ANALYSIS OF FIELD IMPLEMENTING THE "PAVER" PAVEMENT MANAGEMENT SYSTEM

INTRODUCTION

PAVER is an automated pavement management system that provides the user with practical management tools including: data storage and retrieval, pavement network definition, pavement condition rating, project prioritization, inspection scheduling, determination of present and future network condition, determination of maintenance and repair (M&R) needs, performance of economic analysis, and budget planning. PAVER uses the System 2000 (ref 1) as the data base manager. This system and other "interface" programs allow the user to generate preformatted reports of critical information. This information allows objective input to the decision-making process. A complete description of PAVER is provided in refs 2 and 3.

This paper presents an economic analysis of PAVER based on a full-scale field Prototype Evaluation Test (PET) at a U.S. military installation. The official PET monitoring was started on 16 Feb 81 and ran through 15 Jun 81. The military installation's pavements are equivalent to 212 lane miles. The test was monitored by 21 pavement experts from the U.S. Army Corps of Engineers, Major Command Headquarters, and several installations. Two analyses are presented; one based on the PET data only and the other based on the PET data and estimates.

DESCRIPTION OF THE PET

The PET was started by letting a lump sum contract in September 1979 to collect all the necessary information to create a full data base on the military installation's pavements. This contract included the following items:

- (1) Divide the pavement network into branches and sections and provide maps documenting the division.
- (2) Perform a pavement condition survey on all paved areas: roadways, parking areas, motorpools, helipads, runways, taxiways, and aprons.
- (3) Collect pavement structure information from as-built drawings and core borings.
- (4) Collect all information regarding drainage, secondary structures, and shoulders.
- (5) Input data into data base and verify the input.

The total contract price of the data collection was \$91,437. A breakdown of the contract cost and the amount of pavement surveyed is shown in Tables 1A and 1B, respectively. Using the information of Table 1B, a lane mile cost of

inspection was calculated to be \$306/lane mile. Based on the data shown in Table 1B, this reflects the inspection cost for a sampling rate of 51 percent.

It was learned from the PET that the initial sampling rate need not be this high for the initial implementation to provide adequate information on pavement condition. It is anticipated that a sampling rate of approximately 15 percent would be sufficient. Using this reduced sampling rate, an estimated contract cost for full-scale implementation was derived and is shown in Table 2. These values were obtained by linearly interpolating the contract prices for the 51 percent rate.

During the PET, the form shown in Figure 1 was used to record the computer time and man-hours associated with using PAVER and provide an estimate of the time involved in performing each task manually. A portion of the data from the returned forms is shown in Table 3. The hours recorded for M&R project development shown at the bottom of the table were estimated by the Engineering Planning Division at the installation. The 120 hours shown were used with PAVER information in planning a total of 36 projects when end of year money was available. The 480 hours is an estimate of the time to do the same work without the aid of the PAVER system. The installation personnel indicated that without the PAVER system, several projects would have had to be eliminated due to lack of time. Thus, the installation would not have been able to obligate the full amount of monies available to them.

A review of the data indicated that the principal time savings occurred in developing long range plans, budget information reports, M&R cost estimating, and economic analysis. The savings come from the extra computing power offered by PAVER that is not available under the current operating method. Projecting the totals shown in Table 3 over a 1-year period, the following totals are estimated:

- (1) PAVER time: 525 man-hours/year
- (2) PAVER computer time: 17,391 computer charge units (ccu's/year)
- (3) Current method time: 1748 man-hours/year

The ccu's shown were incurred both interactively and through the PAVER "batch process" procedure. Interactive runs cost about \$.12/ccu while the ccu cost in the batch process can vary from \$.015 to \$.075/ccu depending on the selected priority. To develop a weighted average cost for computer usage, the costs and percentages of use shown in Table 4 were used. The percentages of use presented in Table 4 were verified with the installation Buildings and Grounds Division Chief. The resulting average cost based on Table 4 is \$.0765/ccu. The Buildings and Grounds Division Chief indicated that as they become more familiar with PAVER, they are likely to use more of the lower priority (i.e., P01) than indicated from the PET. This will result in a reduced computer cost.

The data presented in this section will be used in the economic analysis in the following sections.

ECONOMIC ANALYSIS

General

The economic analysis of the PAVER system and the current operating method will be developed in the following two ways:

(1) Comparison of the alternatives (i.e., the PAVER system and current method) based on the PET data projected annually. An inherent assumption in this comparison is that the activities performed during the 4 months of the PET represent normal annual operations. This comparison will be referred to from now on as the "PET Data Comparison."

(2) Comparison of the alternatives based on estimated times and costs for expected annual use. The data used for this analysis are based on Table 3 and additional input from the Chief, Buildings and Grounds at the installation. This comparison will be referred to from now on as the "Estimated Data Comparison."

The analysis method used was a present worth analysis using a life of 8 years for the PAVER system.

Assumptions

(1) The installation was selected as an average installation so that the cost of the PET should be representative of costs to implement the system at other installations of similar size. However, the selected installation has employed a manual management system over the past years.

(2) Data processing equipment necessary to operate the automated system will be purchased by the installations (ASCII terminal and acoustical modem). Terminal cost will be distributed over the systems supported by the terminal.

(3) Data base will be maintained for all installations by a single organization. The costs of management will be split between installations for unit cost purposes.

(4) No additional employees will be needed at the installation level to operate the system.

(5) PAVER offers the user more information and procedures than currently available. These items will be considered benefits.

Constraints

(1) The use of PAVER during the four-month PET is not necessarily proportional to a full year's use because different types of activities are required at certain times of the year. Therefore, two analyses are performed as indicated under "General" above.

(2) Time estimates of activities during the PET were made while the PAVER system was in use. Thus, a true dichotomy of tasks was not possible.

Alternative 1 - Current Operating Method

The current method of operation at the installation is a manual card file procedure. This method has been developed by the installation personnel and has been in operation for several years. The procedure basically consists of a card catalogue of pavement sections in which information on pavement structure and past major maintenance is recorded.

(1) PET Data Comparison: The costs based on PET data for the current method consisted of 582.5 man-hours (see Table 3). These hours were split between three engineers, resulting in an average hourly rate of approximately \$15.00/hr. With the total hours shown in Table 3, the current method cost is calculated to be \$8,737 for 4 months or approximately \$26,200/year. These costs are summarized in Table 5.

(2) Estimated Data Comparison: Activities performed during a normal year have been categorized into six groups. The time and costs for these categories are shown in Table 6. The total estimated annual cost is \$17,238/year. These costs are based on discussions with the Chief, Buildings and Grounds at the installation, and a breakdown of the costs in Table 3.

Benefits - Alternative 1

(1) Tangible Benefits: There are no tangible benefits associated with the current method of operation.

(2) Intangible Benefits: There are certain intangible benefits associated with continuing the current method of operation:

(a) The current method is a local method that is user acceptable.

(b) No sophisticated equipment is required.

These benefits, however, are particular to the test installation since most other installations have no manual system.

Risks - Alternative 1

If the current operating method continues, the following risks should be considered.

(1) The number of projects not funded will most likely continue to rise and the total dollar requirement for pavement maintenance will increase.

(2) No common ground of communication will be established between the installation engineers and Major Command engineers.

(3) No objective procedure for pavement rating will be established, reducing the chances for division of maintenance monies based on condition of the pavements.

(4) Continual back-up of work and inconsistent evaluation procedures will decrease pavement life.

Alternative 2 - Automated PAVER

The PAVER system was fully implemented at the installation (i.e., all paved areas were inspected). The initial inspection and data input were performed under a lump sum contract. The actual cost of this initiation along with operation costs from the PET will be considered.

(1) PET Data Comparison: The "operating" costs from the PET for PAVER, as shown in Table 3, are 175 man-hours and 5796 ccu's for computer use. The cost of a man-hour is again the average of \$15.00/hour resulting in a 4-month cost of \$2,628 or approximately \$7,886/year. The computer cost used was \$.0765/ccu as computed in the economic analysis. This yields a computer cost of \$443/4 months or approximately \$1330/year. This is the actual computer time cost; there are also support costs associated with computer use. These can be itemized as follows:

- (a) Connect time* - \$8.50/hour.
- (b) Tape storage - \$0.25/day.
- (c) Disc storage - \$22.00/1000 sectors/month.
- (d) Communication line (telephone) - \$29.00/month.
- (e) Computer paper - \$21.00/box.
- (f) Equipment (terminal and modem) - \$1500.00.

The computer connect time for the PET was approximately 15 hours. Based on the \$8.50/hour rate, the connect time is calculated to be 129/4 months or \$387/year.

Tape storage was not used during the PET so no tape charges are included for the PET analysis. No tapes were used in the PET as a matter of convenience. The present disc storage charge is \$22.00/1000 sectors/month. The installation data base is approximately 700 sectors of disc space. This results in an annual charge of \$1848/year.

Since the military installation Autovon telephone lines will not support teleprocessing equipment, a commercial telephone line was necessary. The monthly charge for the service was \$29/month or \$348/year. No long distance service was required since the computer vendor has an "800" telephone number.

* These costs are based on Boeing Computer Service rates - the Corps of Engineers vendor at the time of the PET.

The terminal equipment for the PET was a Teletype 43 terminal with a 30 character per second acoustical modem. This equipment can be purchased for \$1,500. Since the terminal supports three systems (two in addition to PAVER), only one-third of the cost was assigned to the PET as an initial cost (\$500). Paper needed to support the PAVER system is approximately one box per year at a cost of \$21.00. These costs are summarized in Table 7.

(2) Estimated Data Comparison: As for alternative 1, the activities performed during a normal year have been categorized into six groups. The costs for these groups (Table 8) were estimated through discussion with Chief, Building and Grounds and a breakdown of costs and times shown in Table 3. The annual cost has been divided into \$8,415 for labor, and \$2,948 for computer costs. The computer support cost calculations are shown in Table 9. To reduce overall costs, a tape mount system was assumed to be used in normal annual operation of the PAVER system. A summary of estimated costs for PAVER implementation is presented in Table 10. The initial costs shown are based on the initial cost of the PET (Table 2).

Benefits - Alternative 2

(1) Tangible Benefits: Analysis of specific projects indicated that the use of PAVER could reduce cost of maintenance and have an effect on long-term cost avoidance. One specific project was the Branch IWASN Section 04 (Washington Blvd). As obtained from the installation Contracting Office, the bid price for reconstruction of this section was \$50,417.25. This section was scheduled for an overlay; however, based on its rate of deterioration (from a second PCI inspection), the overlay was estimated to only last 5 years. The reconstruction, on the other hand, is estimated to have a design life of 25 years. The overlay price would have been approximately \$12,173 based on current competitive bid prices. Over the design life of the reconstruction, five overlays would have had to have been placed, resulting in a total cost of \$60,865 without inflation. This represents a cost avoidance of \$10,448. Other cost avoidances are likely to occur due to timely maintenance through the use of readily available information from PAVER. To quantify this cost avoidance, however, several years of data are needed. Therefore, a conservative cost avoidance of only \$10,500 is estimated to occur on an annual basis.

(2) Intangible Benefits: One of the major benefits of using the PAVER system is that the Major Commands will have a uniform method of comparing the pavements at all installations. This will help determine the distribution of maintenance funds and help establish an overall level of service for the installation. This uniform rating will also increase the communication between the Major Commands and the installation engineers. Also, the pavement user will experience greater safety, comfort, and reduced vehicle maintenance because of better overall pavement condition.

At the installation and Major Command level, the PAVER system also adds a great deal of analytical power through programs such as ECON and M&R Guidelines (ref 2). From the PET data, it appears that a time savings of about 2.5 hours can be expected for an economic analysis calculation. This is a benefit to the user, allowing for less computation time. Increased accuracy of the analysis is also expected.

Major benefits experienced at the installation during the PET were that the Work Requirements and M&R guidelines reports were of great use in developing contract documents. These reports provided quantities and cost estimates of the maintenance activities which could take a considerable amount of time to calculate by hand. The quantities were then used in the project preparation phase. The time savings is reflected in the last inputs in Table 3. It was considered to have been impossible to turn out the number of year-end projects (36) without the PAVER system. Having the data stored saved a considerable amount of time in locating documents and reduced the time of field measurements since only spot checking was necessary.

Other Advantages

PAVER also offers the user access to factual data about the condition of the pavement system. Under the current system, this data is the subjective opinion of the pavement engineer. Provision of the objective data allows for more accurate calculations and sounder management decisions. Also, the PAVER system will provide a means for a new pavement engineer to become familiar with the overall network condition and inventory in a short time.

Results of Economic Analyses

The results of the economic analyses are presented in Tables 11 and 12 for the "PET Data Comparison" and "Estimated Data Comparison," respectively. The present worth analysis was performed for an 8-year analysis period assuming a 10 percent interest rate. The analysis was repeated for inflation rates of 0, 5, 10, and 15 percent, respectively. The following is a brief definition of the terminology used in Tables 11 and 12.

- (1) Initial Cost: A one-time cost realized at the beginning of the analysis period.
- (2) Present Value: The cost in today's dollars of the initial cost plus the discounted amount of future costs.
- (3) Equivalent Uniform Annual Cost (EUAC): The present value amortized over the analysis period (present value multiplied by capital recovery factor).
- (4) EUAC/Lane Mile: The EUAC divided by the total number of lane miles of pavement inventoried.
- (5) Total Benefits: The total amount of tangible benefits (in this case, cost avoidance) realized over the analysis period. The total benefits are not discounted.

SUMMARY AND CONCLUSIONS

The economic analysis of the PAVER Prototype Evaluation Test (PET) at a military installation has been presented. Two analyses were performed: (1) an analysis based strictly on the data collected during the 4-month PET (PET Data Comparison) and (2) an analysis based on an average annual estimated data (Estimated Data Comparison). The estimated data were based on the PET data and input from the installation Buildings and Grounds Division Chief.

The results of the economic analyses for the "PET Data Comparison" and the "Estimated Data Comparison" are shown in Tables 11 and 12, respectively. The results of the "PET Data Comparison" for 5 percent inflation are plotted in Figure 2. The figure clearly shows that the annual cost of pavement management using PAVER is approximately 50 percent of the cost of the current system.

The results of the "Estimated Data Comparison" for 5 percent inflation are plotted in Figure 3. The figure shows that the annual cost of pavement management using PAVER is approximately 30 percent of the cost of the current system.

REFERENCES

1. System 2000 is a registered trademark of the INTEL Corporation.
2. Shahin, M. Y., and S. D. Kohn, "Pavement Maintenance Management for Roads and Parking Lots," Technical Report M-294, U.S. Army Construction Engineering Research Laboratory (December 1981).
3. Shahin, M. Y., and S. D. Kohn, "Overview of the PAVER Pavement Management System," a paper submitted for presentation at the 1982 TRB annual meeting.

NAME: _____

ACTIVITY DESCRIPTION: _____

RESOURCES	PAVER	PREVIOUS METHODS	REMARKS
COMPUTER COST			
LABOR HOURS & RATE			

Fig 1. Form Used to Record Time and Cost Data During PET

PET DATA COMPARISON

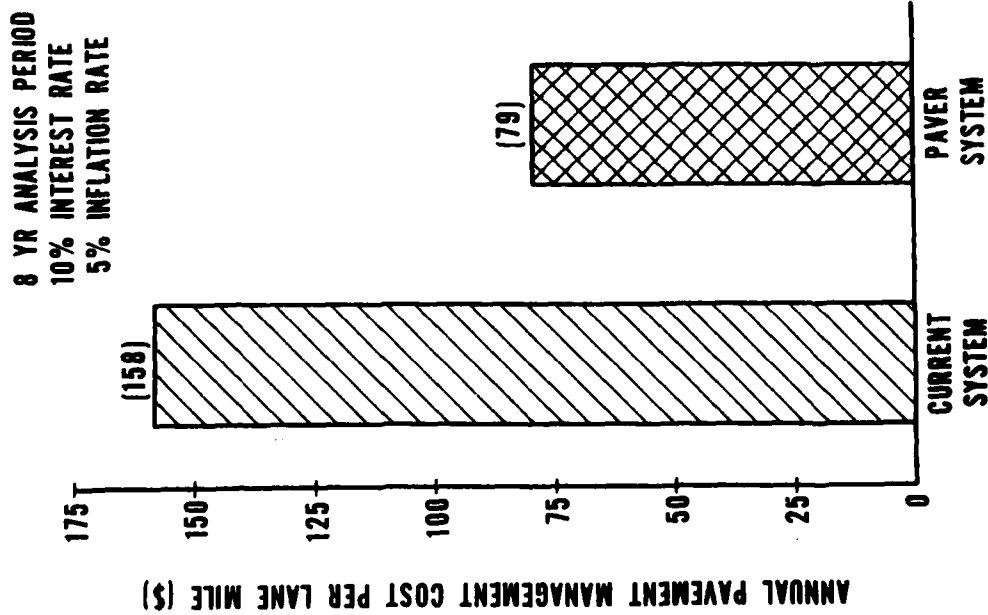


Fig 2. Comparison of Annual Pavement Management Cost Per Lane Mile Based on PET Data.

ESTIMATED DATA COMPARISON

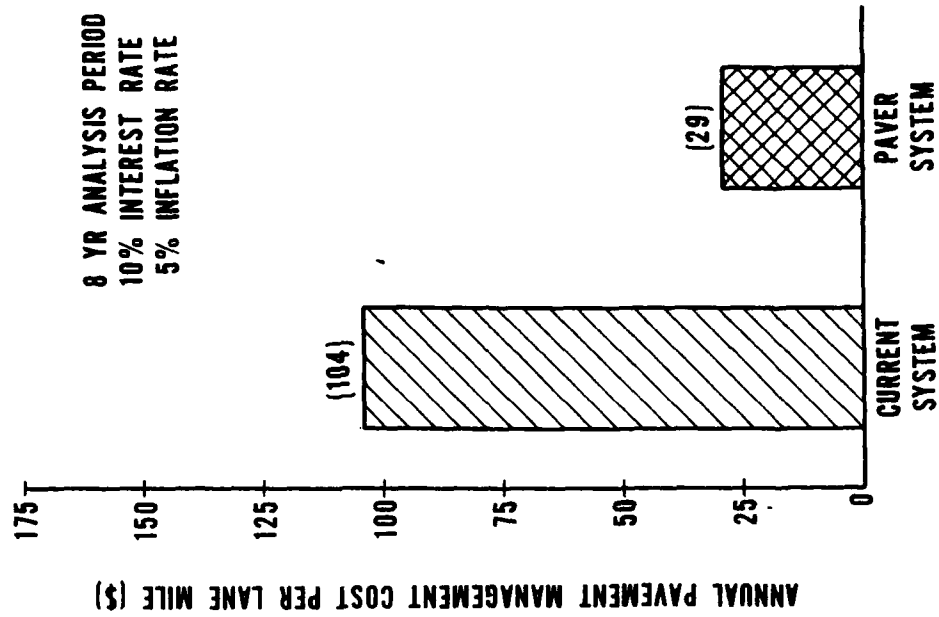


Fig 3. Comparison of Annual Pavement Management Cost Per Lane Mile Based on Estimated Normal Year Data

TABLE 1A
ESTIMATED COST BREAKDOWN OF PAVER PET INITIATION

<u>Item</u>	<u>Cost (\$)</u>
Inspection	64,800
Coring	15,650
Keypunch	1,650
Data verification	9,000
Contract overhead	327
SUBTOTAL	91,427
Additional computer input cost	1,000
TOTAL	\$92,427
Total Lane Mile Cost	\$436/lane mile*
Lane Mile Cost of Inspection	\$306/lane mile

* 1 lane mile = 12.5' x 5280' = 7330 SY

TABLE 1B
AMOUNT OF PAVEMENT SURVEYED

<u>Branch[*] Use</u>	<u>No. of Branches</u>	<u>No. of Sections^{**}</u>	<u>Equiv. Lane mi</u>	<u>Total Sec. Area (SY)</u>
Roadway	94	188	78	569,862
Parking	75	224	88	648,500
MTRPOOL	2	7	25	181,569
Runway	1	1	4	26,431
Taxiway	0	0	0	0
Apron	4	4	16	121,875
Helipad	1	1	1	7,147
TOTAL	177	425	212	1,555,384

Total No. of Sample Units***: 5198
Total No. of Samples Inspected: 2637
Sampling Rate: 50.7 percent

*A "Branch" is an easily identifiable entity of the network such as Washington Blvd., etc.

**A "Section" is a portion of a Branch that is uniform in construction history, structure composition traffic, etc.

***A "Sample Unit" is an inspection unit approximately 2500 sf for asphalt sections and 20 slabs for jointed concrete pavements.

TABLE 2
ESTIMATED FULL-SCALE PAVER IMPLEMENTATION COST AT
15 PERCENT SAMPLING RATE

<u>Activity</u>	<u>Contract Cost</u> <u>(\$)</u>
Inspection	19,100
Key punch (or input)	500
Data Verification	2,600
Computer Time	1,000
Coring	15,650
Terminal Equipment	<u>500</u>
Total	\$39,350

TABLE 3
SUMMARY OF PAVER USAGE AND ESTIMATES OF CURRENT
SYSTEM TIME

Date	Activity	Time, (Hrs)	PAVER Computer Charge Unit (ccu)	Current Time (Hrs)
6/3/81	Develop 200K Bids for SAF	4	135.561	
6/8/81	List of Work Req.	.25	217.222 23.110	
6/13/81	Edit Cost in Work Req.	1.5	598.786	
	Generate Work Req. Rpts. and Add Sect. to Work Req.	1	258.121	
6/20/81	Develop Cont. Projects	.25	187.407	
6/14/81	Develop BMAR Plan			11
6/20/81	Generate Work Req.	.5	116.445	
6/20/81	Generate Areas	.5	29.177	
6/22/81	Inspection			2
6/24/81	Inspection			2
7/81	M&R Proj. Devel. Phase I & II	120		480
	TOTAL	175.25	5796.393	582.5

TABLE 4
COMPUTER TIME PRIORITIES, COSTS, AND PERCENTAGES

<u>Priority</u>	<u>CCU Cost</u> <u>\$</u>	<u>Percent</u> <u>Use</u>
P01	.015	20
P02	.025	
P04	.05	
P06	.06	30
P10	.075	10
P15	<u>.12</u>	<u>40</u>
Weighted Avg. Cost	\$.0765	100%

TABLE 5
COST OF CURRENT METHOD FROM PET DATA

"PET Data Comparison"

<u>Item</u>	<u>Man</u> <u>Hours</u> <u>(4 month)</u>	<u>Avg. Hrly.</u> <u>Rate</u>	<u>4-Month</u> <u>Cost</u>	<u>Annual</u> <u>Cost</u>
Labor	582.5	\$15.00	\$8,739.5	<u>26,200</u>
			Total	\$26,200

TABLE 6

ESTIMATED ANNUAL ACTIVITIES AND COSTS - CURRENT OPERATING METHOD
 "Estimated Data Comparison"

<u>Activity</u>	<u>Hrs.</u>	<u>Avg. Hrly. Rate (\$/hr)</u>	<u>Cost \$</u>
Periodic Pavement Inspection	160	13.44	2,150
Determine M&R Requirements and Set M&R Priorities	240	15.74	3,778
Validation of M&R Projects	80	15.00	1,200
Annual Work Plan	80	14.26	1,141
Long Range Planning	160	15.74	2,518
M&R Cost Estimating	480	13.44	6,451
TOTALS	1200 Hrs.		\$17,238

TABLE 7

COSTS OF PAVER FROM PET DATA
 "PET Data Comparison"

<u>Item</u>	<u>Man Hours (4 month)</u>	<u>Avg. Hrly. Rate</u>	<u>4-Month Cost</u>	<u>Annual Cost</u>	<u>Initial Cost</u>
Labor	175.25	\$15.00	\$2629	\$7886	
Computer ccu's (\$.0765/ccu)			\$443	\$1330	
Computer Connect	15.13	\$8.50	\$129	\$386	
Disc storage				\$1848	
Communication Line (telephone)				\$348	
Paper				\$21	
Terminal Equipment					\$500
Initiation cost					\$92,437
			Total	\$11,819	\$92,927

TABLE 8

ESTIMATED ANNUAL ACTIVITIES AND COSTS - PAVER SYSTEM
"Estimated Data Comparison"

<u>Activity</u>	<u>Time Hrs.</u>	<u>Avg. Hrly. Rate (\$)</u>	<u>Cost (\$)</u>
Periodic Pavement Inspection	160	13.44	2150
Determine M&R Requirements and Set Priorities	96	15.67	1504
Validation of M&R Projects	40	15.00	600
Annual Work Plan	40	14.26	570
Long-Range Planning	24	15.74	378
M&R Cost Estimating	120	13.44	1613
FESA Support 12 mm/all bases			<u>1600*</u>
Labor Subtotal			8415
Computer support			2948
TOTAL	480 Hrs.		\$11,363

*25 Installations requiring one man year GS 12 - $\$26,951 \times 1.5$ (overhead) = \$40,000
 per base = $\$40,000/25$ base installations
 = \$1600/installation

TABLE 9

ESTIMATED ANNUAL COMPUTER SUPPORT COSTS
"Estimated Data Comparison"

1. Tape Loading - 2 times per week (2 time/week)(52 wk/yr)(\$6/mount)	= \$624
2. Update Tape (2 tapes)(35 times/yr)(\$6/mount)	= \$420
	Subtotal \$1,044
3. Tape Storage (2 tapes)(\$.25/day)(365 day/yr)	= \$183
4. On-Line Storage (disc space) \$22/1000 sectors/month Avg. data base size 8000 sectors Assume tape loaded to disc 2 month/yr Annual cost (\$22)(8)(2)	= \$352 Subtotal \$1,579
5. Phone Line	\$348
6. Paper	\$ 21
7. Computer time cost	<u>\$1000</u>
TOTAL	\$2,948

TABLE 10
SUMMARY OF ESTIMATED COSTS FOR PAVER IMPLEMENTATION
"Estimated Data Comparison"

Initial Cost (\$) (see tables 1, 2)	Annual Labor Cost (\$) (see table 8)	Annual Computer Support Cost (\$) (see table 9)
39,350	8415	2948

TABLE 11
SUMMARY OF ECONOMIC ANALYSIS FROM PET DATA
"PET Data Comparison"

A. Current Method
Interest Rate: 10%

Analysis Period: 8 yr.

Inflation Rate (%)	Present Value (\$)	EUAC* (\$)	EUAC Lane Mile (\$)	Total Benefits (\$)
0	153,752	28,820	136	0
5	179,120	33,575	158	0
10	209,600	39,288	185	0
15	246,156	46,140	218	0

B. PAVER System
Interest Rate: 10%

Analysis Period: 8 yrs

Inflation Rate (%)	Present Value (\$)	EUAC (\$)	EUAC Lane Mile (\$)	Total Benefits (\$)	Present Value - Total Benefits (\$)	EUAC Lane Mile (Including Benefits) (\$)
0	162,286	30,420	143	84,000	78,286	69
5	173,729	32,565	154	84,000	89,729	79
10	187,479	33,142	166	84,000	103,479	92
15	203,969	38,233	180	84,000	119,969	106

*Equivalent Uniform Annual Cost.

TABLE 12

SUMMARY OF ECONOMIC ANALYSIS ESTIMATED ANNUAL COST DATA
"Estimated Data Comparison"

A. Current Method - Estimated Costs				Analysis Period: 8 yrs.			
Interest Rate: 10%							
Inflation Rate (%)	Present Value (\$)	EUAC (\$)	EUAC Lane Mile (\$)	Total Benefits (\$)			
0	101,160	18,962	89	0			
5	117,850	22,090	104	0			
10	137,904	25,849	122	0			
15	161,955	30,358	143	0			

B. PAVER System				Analysis Period: 8 yrs			
Interest Rate: 10%							
Inflation Rate (%)	Present Value (\$)	EUAC (\$)	EUAC Lane Mile (\$)	Total Benefits (\$)	Present Value Total Benefits (\$)	EUAC Lane Mile (Including Benefits) (\$)	
0	106,027	19,874	93	84,000	22,027	20	
5	117,027	21,936	115	84,000	33,027	29	
10	130,246	24,414	115	84,000	46,246	41	
15	146,099	27,385	129	84,000	62,099	55	

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